The cognitive economy

Harnessing artificial intelligence as an engine of progress and prosperity

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Despite the economic upheaval of the last twenty years, the world has been forging the foundations of a long-lasting period of global economic expansion. The digital disruption taking place within enterprises and across industries is transforming markets. It has also set the stage for dramatic increases in productivity, profitability, employment, and income.

The adoption of advanced capabilities like cognitive computing and artificial intelligence (AI) will enhance and accelerate this economic growth. Machines that learn and make sense of vast stores of unstructured information have the potential to substantially augment human capability in nearly every profession. And they will profoundly affect the nature of work.

In particular, AI will redefine the specific tasks that comprise most occupations. While the vast majority of them will persist, employers will need to reorganize tasks within those occupations, and redefine the skills needed to successfully complete those tasks.

We are still in the early stages of this transformation; the full economic potential of AI won't be realized for decades to come. But IBM is optimistic about this potential for progress and prosperity. Because of the expected increase in productivity, we believe strongly in cognitive computing's ability to accelerate widespread economic growth and improve standards of living in both developed and developing countries. And we are working closely with economists, academics, and policymakers to understand the economic effects and to guide them in a way that benefits all humankind.

A brief history of technological revolution

The world has been here before. The Information Age is the fifth technology revolution in modern history. There was the first Industrial Revolution in the late 1700s, fueled by the mechanization of the cotton industry, machinery, and the harnessing of water power; the age of steam and railways in the early 19th century; the age of steel and electricity in the late 19th century; and the age of oil and automobiles that dominated most of the last century.

Each revolution follows what is now a familiar pattern. Each begins with new, powerful technology (power loom, steam engines, heavy engineering, and mass production) that either necessitates or enables new network infrastructure (canals, railways, electric power, and roads) to distribute the economic impact. And each is met with frenzied investment, an early boom-and-bust cycle, and ultimately an extended period of economic maturity in which wealth and prosperity is widely distributed.

"Each time around, what can be considered a 'new economy' takes root where the old economy had been faltering. But it is all achieved in a violent, wasteful, and painful manner," says Carlota Perez, the British scholar of technological paradigm shifts and author of *Technological Revolutions and Techno-Economic Paradigms.* Among the economic side effects of this chaotic period are income inequality and fierce resistance to change. But social institutions such as governments and schools eventually catch up, and the economic benefits spread.

"If, at this turning point, the institutional adjustment is successfully achieved, what follows may be a golden age," says Perez. "It can be a period of full employment and widespread productive investment, a period when production is at center stage, when at last the benefits of the system begin to spread down and an era of 'good feeling' sets in."[i]

For the last twenty years, financial markets have endured expected disruption and upheaval following the frenzied adoption of the Internet and digital technology. But this has been a prelude; the dawn of Perez's "Golden Age." Debt has been drawn down. Financial markets have stabilized. And healthy, sustainable economic growth is finally taking hold.

"Even if Moore's Law ground to a halt today, we could expect decades of complementary innovations to unfold and continue to boost productivity," writes MIT economists Erik Brynjolfsson and Andrew McAfee in *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Machines.* "The path won't be smooth…but the fundamentals are in place for bounty that vastly exceeds anything we've ever seen before."[ii]

We know more than we can tell

In 1966, a Hungarian polymath named Michael Polanyi described the unique cognitive abilities of humans by saying "We know more than we can tell." What came to be known at Polanyi's Paradox is a succinct way of saying that much of human knowledge is tacit, or personal, in nature. It is transmitted through culture and evolution; it manifests as intuition or instinct. As such, it cannot be taught or even articulated in any direct form, though it can be learned through experience and immersion (riding a bicycle, for example).

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For decades, this paradox defined the limitations of programmable software. If a developer was unable to consciously understand or express the rules or procedures that guide an action, that action could not be translated into code; it could not be automated.

AI helps to overcome Polanyi's Paradox. In particular, AI refers to systems that can be taught, much like humans, through interaction and repetition. Rather than relying explicitly on written code, they learn. And AI systems can generate answers to more than numerical problems; they can make sense of unstructured information, create hypotheses, and find patterns. And though it is still early, companies in nearly every country and every industry are beginning to understand how to apply this technology to greatly scale human capability.

For example, doctors can use it to mine millions of pages of medical research and inform personalized treatment plans for cancer patients. Oil rig workers can use it to access thirty years of predecessors' experience and expertise to make a safer work environment. And tax preparers can use it to scour thousands of pages of tax code to find every possible deduction for a client.

In the cognitive economy, humans and machines work side by side, with technology augmenting our ability to make better informed, less biased decisions. History and current research suggest the economic impact of these capabilities could be enormous, allowing entirely new markets and industries to blossom. In research published in 2017, McKinsey & Company estimated that automation supported by AI could raise productivity growth globally by as much as 1.4 percentage points annually.[iii]

The future of work: human + machine

Throughout history, every major transformational technology has been met with fears of job loss and displacement. And every time, the exact opposite happens.

From the Luddite movement of the 1800s to Lyndon Johnson's *Blue Ribbon Commission on Technology, Automation, and Economic Progress*, anxiety over automation's ability to outstrip demand for labor is a modern economic leitmotif. And it's not without reason. Automation does replace human labor, as it is intended to do. But the beneficial economic effects of automation – from the power loom to the ATM machine – often grow net employment, both in their own industries and in adjacent industries, by driving increased access to – and demand for – products and services.[iv]

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"It might seem obvious that if ATMs do the work of bank tellers and accounting software does the work of bookkeepers, there will be fewer jobs for bank tellers and bookkeepers. But that reasoning is fallacious," says James Bessen, an economist at Boston University, and author of *Learning by Doing: The Real Connection Between Innovation, Wages, and Wealth.* ATMs did, in fact, automate some bank teller tasks. In so doing, however, it lowered the cost of opening and operating bank branches, and refocused the emphasis of employees on forging client relationships and introducing new financial products. The end result was a 43 percent increase in the number of bank branches between 1988 and 2004. And an increase in the number of branch employees.[v]

"Thus the story that machines replace labor and reduce overall employment and wages is too simplistic," says Bessen. "Just as with weaving, machines could perform some tasks, but they increased demand for other tasks."

This frame of identifying the individual tasks that comprise occupations is useful when trying to understand the effect of AI on the workforce. Unlike the rules-based technologies historically used to automate certain tasks in the manufacturing sector, AI technologies understand, learn, and perform many tasks that comprise today's much larger services sector.

Thus, AI complements knowledge work in the same way that automation complemented physical labor. In his paper *Why Are There Still So Many Jobs? The History and Future of Workplace Automation*, MIT economics professor David Autor explains this theory of complementarity: "I argue that the interplay between machine and human comparative advantage allows computers to substitute for workers in performing routine, codifiable tasks while amplifying the comparative advantage of workers in supplying problem-solving skills, adaptability, and creativity… In many cases, machines both substitute for and complement human labor. Focusing only on what is lost misses a central economic mechanism by which automation affects the demand for labor: raising the value of the tasks that workers uniquely supply."[vi]

This is not to say that no jobs will be lost. Workers in some occupations will inevitably be displaced and

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unable to find new work without gaining new skills. But if history is any indication, the number of occupations that will actually disappear will be minimal. And early research on the subject bears that out.

In 2017, a group of U.S. scholars combined occupational data with recruitment advertising text and applied natural language processing to analyze changes to the tasks performed in more than 700 occupations over 40 years from 1960 to 2000. The work makes clear distinctions between occupations (work or a profession that consists of the performance of a collection of tasks), tasks (a unit of work that delivers output), and skills (a worker's endowment of capabilities in performing tasks.)

At the highest level, recent data show that 93 percent of occupations persist, with 7 percent of occupations newly occurring and disappearing.[vii] The new occupations, not surprisingly, tend to be in scientific and engineering fields where innovation is occurring rapidly. As the existing occupational structure maintains a high degree of stability over an extended period, enterprise and labor market transformation occurs largely in the reorganization of tasks within occupations.[viii]

That is to say, the vast majority of jobs as we currently know them will be transformed – along with the organizations that supply them – as tasks are completed by some combination of human and machine. For this reason, we believe the focus of societal concern should not be preparing for millions to be rendered jobless. Rather, it should be about taking full advantage of the opportunity before us, empowering workers across all occupations with the skills and tools they need to reap the benefits of these new technologies, and developing multiple pathways for those skills to be acquired throughout the stages of a person's working life.

Technology is not destiny

Like the power loom or steam engine before it, AI will do more than redefine how the world works. Over time, it will expand what people are able to work on, opening up entirely new avenues of exploration, discovery, and industry. In so doing, it will create new markets and companies, and transform existing enterprises and government institutions from top to bottom. But this process will not occur in a vacuum, nor is it solely or even primarily determined by the technology itself. Together, business and government leaders can and must articulate the social contract that shapes this change, maximizing its benefits and minimizing its risks.

In particular, companies that deploy these technologies should take steps to ensure that development and adoption is done responsibly. To guide this work, IBM has developed three principles that we believe all organizations should consider as we enter into the cognitive economy.

- **Purpose:** The purpose of AI systems should be to augment human intelligence, not replace it.
- **Transparency:** The public should be made aware of when and where AI systems are being applied and the sources of data they use.
- **Skills:** The knowledge and skills required to help students, workers, and citizens engage safely, securely, and effectively in relationships with AI systems, and to perform the new kinds of work and jobs that will emerge in an AI economy, should be made readily available.

This last point is particularly relevant to sharing the benefits of the cognitive economy across developed and developing countries, and across all socio-economic strata. Boston University's Bessen has studied the wage stagnation and income inequality that often accompanies the early adoption of labor-saving technology; the lag between the introduction of new technology and the development of the skills required to manage it.

"Developing the knowledge and skills needed to implement new technologies on a large scale is a difficult social problem that takes a long time to resolve," says Bessen. "It was a difficult problem in the past and remains so today, yet most workers will only benefit once it is resolved. Resolution will take time and the right policies."[ix]

To reduce the lag time between technology advances and requisite skills, enterprises and their workforces need more access to programs that prioritize skills development and capabilities over university degrees and broad-based academic credentials. It is no longer enough to prepare students for traditional "blue collar" or "white collar" jobs. "New collar" roles, found in some of the technology industry's fastest growing fields – from cloud computing and cybersecurity to digital design and cognitive computing – offer a new and promising route to meaningful employment in the cognitive economy.

Many new collar jobs that do not require a four-year degree are opening up career opportunities for low-income or otherwise disadvantaged students who bring greater diversity – and innovation – into the workforce. Examples include jobs in app development, network security, and data mining; the skill sets required for positions in these fields are in high demand.

Five years ago, IBM founded a new kind of school model designed to develop these and other skills. The P-TECH 9-14 school model fosters partnerships among high schools, community colleges, and industry, and prepares young people with high-demand technical and professional skills. P-TECH students graduate with both their high school diploma and a two-year postsecondary degree, based on a curriculum mapped specifically to industry needs. There are now 70 P-TECH schools across six U.S. states, Australia, and Morocco, with additional schools planned.

New collar positions account for about 15 percent of IBM's U.S. hiring. And the company has committed more than $1 billion over the next four years to help prepare the workforce for these emerging roles. But more work is needed.

The work ahead

In 1900, nearly half of the labor force in the U.S. was employed in the agriculture industry.[x] Today, that number has dwindled to less than 2 percent, a decline that mirrors the trajectory of the rest of the developed world. Farm equipment, irrigation, genetic engineering, and new methods of cultivation have resulted in higher yields and more efficient production, greatly reducing the demand for farm labor over time.

The rate and pace of social transformation must match the rate and pace of technological change

Why wasn't widespread unemployment the result? Because government institutions, business leaders, and the labor force itself worked together to adjust to the changing dynamics of the labor market and transform the workforce. One way they did that was by making high school a core element of the common school system, increasing secondary school enrollment tenfold between 1890 and 1920, and preparing a workforce capable of meeting the needs of the growing white-collar sector.

A similar social contract is needed today. The rate and pace of social transformation must match the rate and pace of technological change. To do this, the same constituents must again work in concert to transform the workforce in the age of AI: the enterprises that hire and train workers; the government institutions that set education and regulatory policy; and the individuals that constitute the workforce. Each bear specific responsibility, and each have strong incentive to fulfill that responsibility:

- **Enterprises** must invest in skills development as part of their digital transformations, understanding, valuing, and developing a diversity of skills – including soft skills – to make employees less vulnerable and their companies more competitive.
- **Governments** must commit to education reform, including the realignment of curriculum with market needs and a commitment to transition support and retraining of workers to facilitate movement between jobs, fields, and employers.
- **Individuals** must commit to a lifetime of learning and career evolution, diversifying their skill sets and embracing changes in employment opportunity.

We have before us an unprecedented opportunity, with sufficient advance notice and ample historical reference, to guide the cognitive economy so that it benefits all of humankind. To discover mysteries of the universe. To cure disease. To drive productivity and GDP. And yes, to create new jobs and increase wages across the board. We need only to understand the nature of this change and guide it with purpose.

To learn more about IBM's specific policy recommendations, read "Growing Digital Jobs and Advantage for Workers."

[i] Carlota Perez (2009); *Technological Revolutions and Techno-Economic Paradigms;* Technological University of Tallinn, Estonia, University of Cambridge, and University of Sussex, U.K.; January 20, 2009.

[ii] Erik Brynjolfsson and Andrew McAfee (2014); *The Second Machine Age: Work, Progress, And Prosperity In A Time Of Brilliant Machines;* W.W. Norton & Company; 2014.

[iii] McKinsey Global Institute (2017); *A Future That Works: Automation, Employment, And Productivity;* McKinsey Global Institute; January 2017.

[iv] David Autor and Anna Salomons (2017); *Does Productivity Growth Threaten Employment?*; Paper prepared for the ECB Forum on Central Banking, June 19, 2017.

[v] James Bessen (2015); *Learning By Doing: The Real Connection Between Innovation, Wages, And Wealth;* Yale University Press; 2015.

[vi] David Autor (2015); *Why Are There Still So Many Jobs? The History And Future Of Workplace Automation*, Journal of Economic Perspectives; Summer 2015.

[vii] Robert D. Atkinson and John Wu (2017); *False Alarmism: Technological Disruption and the U.S. Labor Market, 1850–2015*; Information Technology Innovation Foundation; May 2017. Atkinson and Wu provide a similar calculation and conclude that "contrary to popular perception, rather than increasing over time, the rate of occupational churn in recent decades is at the lowest level in American history." Occupational churn was 6% in the first half of the 2010s. See page 14, Figure 7.

[viii] Enghin Atalay, Phai Phongthiengtham, Sebastian Sotelo, Daniel Tannenbaum (2017); *The Evolving U.S. Occupational Structure: A Textual Analysis;* July 2017.

[ix] See Bessen (2015).
[x] See Autor (2015).

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