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Skills and Jobs in the Digital Economy

Few subjects are as important or as challenging to predict as the future of jobs in our emerging digital economy. While the U.S. unemployment rate continues to improve–finishing 2014 at 5.6% or 8.7 million people–almost one third of the unemployed have been jobless for over 27 weeks. The total number unemployed or underemployed–what economists call the U6 unemployment rate–stands at 11.2% or 17.4 million people. And the employment to population ratio remains at under 60%, the lowest such percentage since the 1970s. “The economic challenge of the future will not be producing enough. It will be providing enough good jobs,” wrote Harvard professor and former Treasury Secretary Larry Summers in a recent WSJ article.

Technological revolutions are highly disruptive to economies and societies. This was the case for much of the Industrial Revolution, as is the case today. “The digital revolution has yet to fulfil its promise of higher productivity and better jobs,” said The Economist in a special report on Technology and the World Economy in its October 4th issue. “The modern digital revolution – with its hallmarks of computer power, connectivity and data ubiquity – has brought iPhones and the Internet.” But, “it is disrupting and dividing the world of work on a scale not seen for more than a century. Vast wealth is being created without many workers; and for all but an elite few, work no longer guarantees a rising income.”

Middle class jobs have been in decline for the past few decades in the U.S. and other advanced economies, – particularly since 2000. And the livelihood of significant additional workers is potentially threatened, as our increasingly smart machines continue to be applied to activities requiring cognitive capabilities that not long ago were viewed as the exclusive domain of human. How will these relentless advances in technology and automation affect the balance between humans and machines in the workplace, and the skill composition of future jobs?

This critical question was addressed in a recent paper, Racing With and Against the Machine: Changes in Occupational Skill Composition in an Era of Rapid Technological Advance, by MIT’s Frank MacCrory,George Westerman and Erik Brynjolfsson along with Yousef Alhammadi from the Masdar Institute in Abu Dhabi. The paper analyzed the changes between 2006 and 2014 in the skill composition of 674 occupations using the US Government’s O*NET data base, the most comprehensive data sets of occupational skill requirements. The period from 2006 to 2014 saw the advent of several major digital innovations,

including smart mobile devices, social media, big data and analytics, cloud computing and the Internet of Things.

The paper's overall findings are summarized in its abstract. "Consistent with theory, we find a significant reduction in skills that compete with machines, an increase in skills that complement machines, and an increase in skills where machines (thus far) have not made great in-roads. Complementarity across skills has increased, boosting the need for worker flexibility. The remarkable scale and scope of occupational skill changes that we document just since 2006 portend even bigger changes in coming years."

Economists have long been examining these changing job dynamics.In 2003, David Autor, Frank Levy and Richard Murnane developed a framework for looking at the impact of technology on various classes of jobs. They segmented work tasks along two dimensions: whether they were cognitive or manual; and whether they were routine or non-routine, resulting in a 2 X 2 matrix:

Routine, cognitive tasks can be well described by a set of rules, including calculations, record keeping, handling simple customer service questions, and many kinds of administrative tasks. These white-collar activities have been prime candidates for technology substitution or automation.
Routine, manual tasks can also be well described by a set of rules, including those involved in manufacturing and other forms of production. These blue-collar activities have also been prime candidates for technology substitution.
Non-routine, manual tasks cannot be described by a set of rules that a machine can follow. Many low skill, low pay activities fall into this category, such as janitorial services, gardening, fast-food restaurant jobs and health care aides. In the past, these activities have not been candidates for technology substitutions, nor where they easy to complement with technology-based tools.
Non-routine, cognitive tasks tend to be high-skill human activities that involve expert problem solving and complex communications for which there are no rule-based solutions. Computers have significantly complemented and increased the productivity of high-skill, information-intensive jobs, enabling them to address many new kinds of problems.

Racing With and Against the Machine expands on this work. The authors analyzed the 674 occupations in the O*NET data base, empirically derived a key set of skill categories or factors, and examined the changes in skill factors between 2006 and 2014.

7 distinct skills factors were extracted from the 2006 occupations data base:

Manual: Dynamic strength, Gross body coordination, Handling physical objects, Manual dexterity, Speed of limb movement, Stamina, ...
Equipment: Equipment Maintenance, Installation, Operation Monitoring, Repairing, Systems analysis, Troubleshooting, ...
Supervision: Coordinate others' work, Develop/build teams, Guide/motivate subordinates, Manage

financial resources, Monitor resources, Schedule work or activities, ...
Perception: Category flexibility, Far vision, Perceptual speed, Selective attention, Speed of closure, Visual color discrimination, ...
Interpersonal: Adaptability, Assisting or caring for others, Cooperation, Dependability, Service orientation, Stress tolerance, ...
Initiative: Achievement, Independence, Initiative, Innovation, Persistence, ...
Vehicle Operation: Operate vehicles, Night vision, Peripheral vision, Sound localization, Spatial orientation, ...

The analysis was repeated for the 2014 occupations, yielding 5 distinct skill factors:

Cognitive: Complex problem solving, Critical thinking, Deductive reasoning, Oral comprehension, Speed of Closure, Written expression, ...
Manual: Equipment Maintenance, Finger dexterity, Handling physical objects, Multi-limb coordination, Reaction time, Visual color discrimination, ...
Supervision: Coordinate others' work, Develop/build teams, Guide/motivate subordinates, Manage financial resources, Monitor resources, Schedule work or activities, ...
Interpersonal: Adaptability, Assisting or caring for others, Cooperation, Dependability, Service orientation, Stress tolerance, ...
Initiative: Achievement, Independence, Initiative, Innovation, Persistence , ...

The skills content in three of the 2014 factors remained largely the same: *Initiative*, *Interpersonal* and *Supervision.* Not surprisingly, these are the factors that technology is still not particularly good at automating or complementing.

The *Manual* factor changed considerably. In 2006 it included an emphasis on strength and stamina, both of which were significantly reduced in 2014 by advances in technology. On the other hand, the *Manual* factor saw an increased emphasis on the human ability for using and maintaining increasingly complex machines.

Technology had its biggest impact on the 2006 *Equipment*, *Perception* and *Vehicle Operation* factors, causing them to be subsumed into a new 2014 *Cognitive* factor.

After closely examining these changes in skill requirements between 2006 and 2014, the authors identified the major trends they portend, which are likely to continue over the next decade as well.

The importance of "manual" skills within jobs has decreased over time. "Past automation has replaced routine manual tasks and can be expected to continue to do so. Meanwhile, technology advances now allow computers to do several manual tasks that are non-routine. Google's autonomous car and Rethink robotics' Baxter are two examples of relatively difficult manual tasks that can now be performed by computers. Factory automation is transforming many

other jobs, from painting automobiles to sorting mail to picking products in warehouses."

The importance of "perception" skills within jobs has decreased over time. "An important recent change in technological capability has been in the area of perception. There have been remarkable advances in robotic vision and perception that would have been the domain of science fiction ten or twenty years ago. For instance, computers are now are able to understand speech in ways they never could before… Similarly, computer vision capabilities have advanced rapidly for tasks such as distinguishing objects, understanding writing, and identifying production defects on assembly lines… Thus we expect a substitution of technology for labor in occupations that relied on routine human perception, particularly in cases that favor the machines' inherent advantage of consistent performance over long periods without breaks."

The importance of "interpersonal" skills within jobs has increased over time. "One important area in which computers still trail humans is interpersonal interaction… More complex interpersonal interactions, such as those in sales, customer service, and supervision, remain the domain of human workers. We can expect that occupations will shift toward those skills in which humans have a relative advantage over machines. Machines have demonstrated limited ability to perform interpersonal tasks, and human customers have a preference for interacting with other humans."

The importance of workers' facility with technology has increased over time. "While technology can substitute for labor in many occupations, it can augment human skills in others. Computerized systems are making workers, from call centers to factories, more productive. Digital tools provide graphic artists and product designers with the ability to work more quickly and flexibly than ever before. Workflow and collaboration tools improve coordination and knowledge sharing among workers. At the high end of the skill distribution, medical diagnostics, electronic medical records, and technology- assisted surgery are improving physician productivity and patient outcomes. As technology substitutes for some skills, it can also serve as a complement that increases the need for, and the productivity of, skills that computers cannot yet perform."

The skills that are important within jobs will change over time. "Complementarity across skills has changed, creating an increased need for workers to be flexible in their skill development. One striking example is that facility with technology has become such a common job requirement that it is no longer a major differentiator between jobs… For any given skill one can think of, some computer scientist somewhere may already be trying to develop an algorithm to do it. So, workers – especially those with many years left in their careers – need to stay flexible in focusing on new skills or finding occupations with new complementarities."

These major changes are likely to accelerate, given the continuing advances in many

digital technologies. “This suggests that the significant economic disruption – and the large changes in the demand for skills like perception, supervision, interpersonal facility, and equipment use – are likely to grow. The disruption is an opportunity for organizations, but may be a threat to many workers. Researchers, managers and policymakers need to understand these changes if they are to diagnose them correctly and ultimately prescribe effective solutions.”

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