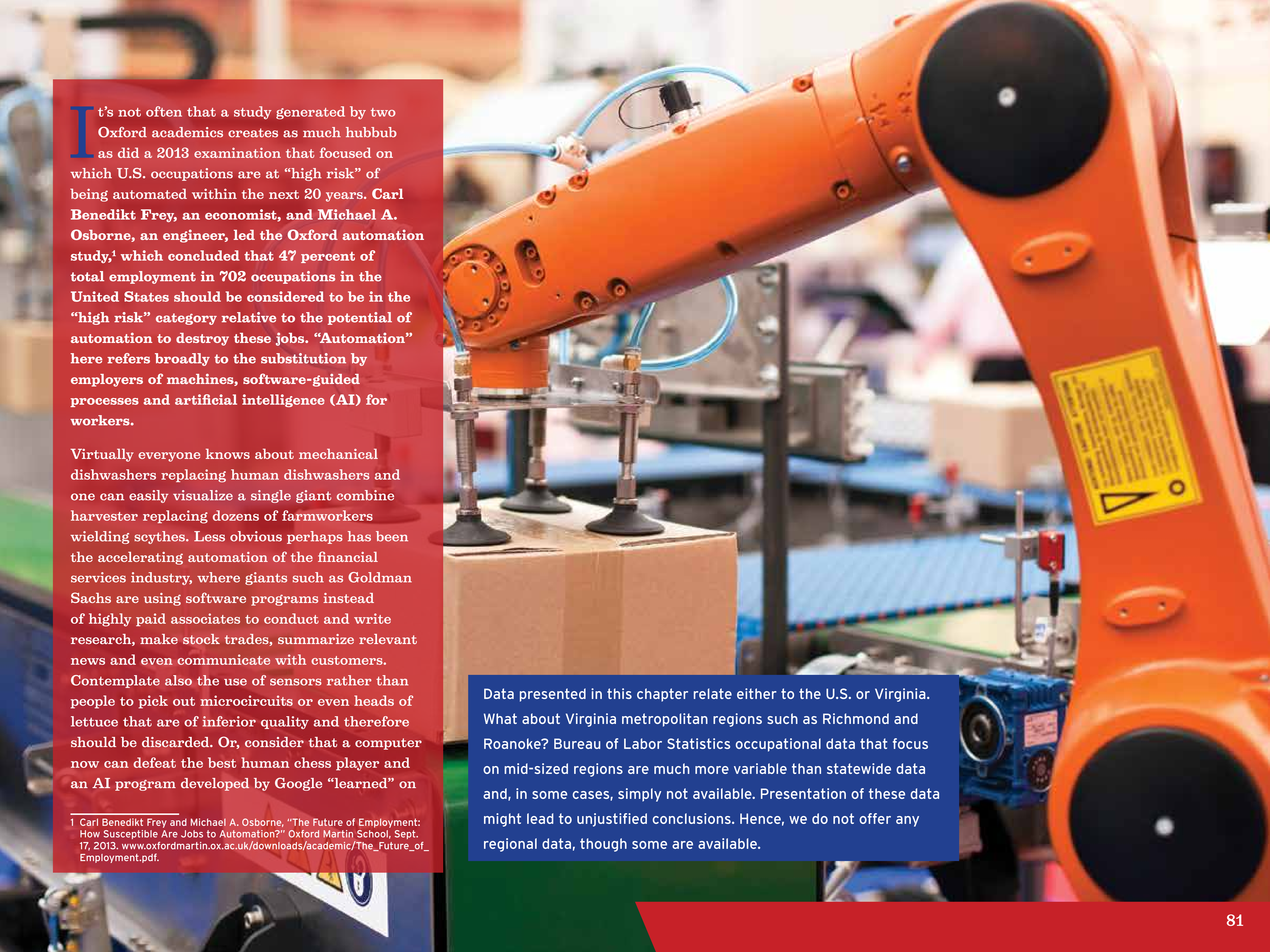
# WILL ROBOTS TAKE YOUR JOB? A LOOK AT VIRGINIA'S OPPORTUNITIES AND VULNERABILITIES

*It's not about the skill level or how much education you have. Really, the primary question is, is the job on some level routine, repetitive and predictable?*

– Martin Ford, "Rise of the Robots" (Basic Books, 2015)



It's not often that a study generated by two Oxford academics creates as much hubbub as did a 2013 examination that focused on which U.S. occupations are at "high risk" of being automated within the next 20 years. **Carl Benedikt Frey, an economist, and Michael A. Osborne, an engineer, led the Oxford automation study,[1] which concluded that 47 percent of total employment in 702 occupations in the United States should be considered to be in the "high risk" category relative to the potential of automation to destroy these jobs. "Automation" here refers broadly to the substitution by employers of machines, software-guided processes and artificial intelligence (AI) for workers.**

Virtually everyone knows about mechanical dishwashers replacing human dishwashers and one can easily visualize a single giant combine harvester replacing dozens of farmworkers wielding scythes. Less obvious perhaps has been the accelerating automation of the financial services industry, where giants such as Goldman Sachs are using software programs instead of highly paid associates to conduct and write research, make stock trades, summarize relevant news and even communicate with customers. Contemplate also the use of sensors rather than people to pick out microcircuits or even heads of lettuce that are of inferior quality and therefore should be discarded. Or, consider that a computer now can defeat the best human chess player and an AI program developed by Google "learned" on

1 Carl Benedikt Frey and Michael A. Osborne, "The Future of Employment: How Susceptible Are Jobs to Automation?" Oxford Martin School, Sept. 17, 2013. www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.

Data presented in this chapter relate either to the U.S. or Virginia. What about Virginia metropolitan regions such as Richmond and Roanoke? Bureau of Labor Statistics occupational data that focus on mid-sized regions are much more variable than statewide data and, in some cases, simply not available. Presentation of these data might lead to unjustified conclusions. Hence, we do not offer any regional data, though some are available.

its own how to beat the reigning world champion at Go, the exceedingly complex 2,500-year-old strategy game.

An increasing number of McDonald's restaurants now have computer screens that take your order – rendering unnecessary some of the workers formerly behind the counter. No minimum-wage law applies to the computer screens. In the realm of higher education, the advent of new distance-learning tools and the rise of "MOOCs" (massive open online courses) are disrupting the centuries-old "sage on the stage" model that emphasizes professors lecturing to groups of more or less interested students arrayed in front of them.

Highest on the risk list are occupations that include telemarketers, tax preparers, library technicians, etchers and engravers, and bank tellers. Frey and Osborne argue that up to 87 percent of jobs in the accommodation and food services sector are at risk, as are up to 54 percent of jobs in finance and insurance. Lowest on their risk list are occupations such as elementary school teachers, doctors and dentists, nurses, many health care workers, plumbers, theatrical makeup artists and foresters.

## The Common Denominator

What determines whether the jobs of workers in some occupations (say, secretaries and legal researchers) are at high risk, while the jobs of workers in other occupations (nurses and plumbers) are not? **The key is not necessarily the level of education required for each job, though this may play a role. Instead, the overriding deciding factor is the extent to which jobs require creative and social intelligence, perception, interpretation and the ability to manipulate as opposed to being dominated by repetitive, routine tasks capable of being learned by machines fueled by artificial intelligence.**

Some analysts believe that Frey and Osborne's estimates are substantially too high. A 2016 Organization for Economic Cooperation and Development (OECD) study takes issue with their methodology and argues that it isn't all workers in an occupation that are at risk, but rather specific jobs within occupations. Thus, some workers at financial firms can readily be supplanted by trading algorithms incorporated into software, while others cannot be replaced because of their personal relationships with specific firms and customers. The OECD study concludes that only 9 percent of all jobs are at risk because of automation (Melanie Arntz, Terry Gregory and Ulrich Zierahn, "The Risk of Automation for Jobs in OECD Countries," www.oecd-ilibrary.org, May 2016). A July 2016 study produced by McKinsey analysts Michael Chui, James Manyika and Mehdi Miremadi ("Where Machines Could Replace Humans – and Where They Can't (Yet)," www.mckinsey.com/business-functions/business-technology/our-insights/where-machines-could-replace-humans-and-where-they-cant-yet?cid=other-eml-alt-mkq-mck-oth-1607), concluded that 60 percent of all occupations in the United States could see 30 percent or more of their work activities being automated.

Note that job recovery in the United States (and Virginia) from the Great Recession of 2008 has been built upon relatively low-skill service jobs that pay relatively low wages. It is often these jobs that Frey and Osborne argue are most at risk because of automation. The reason is that they involve repetitive tasks that can be programmed into a machine or computer. Further, the machine frequently can complete those tasks with a higher level of quality and do so at a lower per-unit cost than their human counterpart. Think about the computer screen that is taking the place of behind-the-counter personnel at Panera Bread.

The reality is that computerization of jobs no longer is confined to traditional assembly-line, mass-production industries. However, it also is true that some manual labor tasks require physical adaptability and flexibility in approach. Hence, workers doing these tasks are more resistant to automation than those in other jobs that often require more education, but nevertheless can be imitated by "smart" machines.

It is the exercise of reasoning, judgment and creative abilities plus the application of social interaction skills that most frequently cause a job to fall into the low automation risk category rather than high risk. One does not need a bachelor's degree to become an electrician or a plumber (both low-risk occupations). Nevertheless, electricians, automobile mechanics and plumbers must be able to assess, interpret, adjust, reason and create when inserted into unpredictable situations. "You never know what kinds of wiring and connections you're going to find in an old house," a veteran electrician told us. Some variant of this observation, however, might be applied to nurses, engineers and multimedia artists. On-the-job experience often assumes great value in such positions because it provides workers with a set of proficiencies that enables them to exercise sound judgment in situations that seldom are repetitive.

On the other hand, the tasks confronting a telephone operator, shipping clerk or Las Vegas gaming employee tend to be repetitive and frequently can be replaced by a smart machine. True, these jobs usually require less formal education than those in low-risk occupations. However, it is not education per se that makes the difference here, but rather the presence or absence of repetitive tasks, reasoning and creativity.

**The principle is straightforward: Repetitive, predictable tasks are susceptible to machine learning and the application of artificial intelligence. Thus, college professors, despite their Ph.Ds., may indeed find some of their number being replaced by learner-driven technology that is capable of doing what they do, but at a reduced cost.** Ironically, the learner-driven technologies with access to abundant data and feedback may actually be more sensitive than the typical college professor is to the peculiar geographic locations, job and family situations, and learning preferences of individual students.

Contrast college professors to elementary school teachers, very few of whom hold a doctorate. These teachers cannot be replaced by a machine because of their need to exercise judgment, interpret what is going on in their sometimes unpredictable classrooms, develop individually focused plans of action on the fly, and use their social skills to deal with impressionable and sometimes delicate young people. Elementary school teachers are among the least at-risk workers in society today.

## What The Studies Say (And Do Not Say)

Neither Frey and Osborne, nor the OECD or McKinsey Global Institute, are rigid determinists. They speak in terms of probabilities ("susceptibilities") rather than certainties. The future they paint is a plausible one, yet not one that is inevitable. Why?  Because technological change and changing prices may alter the world they have addressed. Consider the following situations.

- Think of a new machine that is capable of performing many of the tasks of a software engineer; however, this machine is prohibitively expensive and hence what is feasible is not economic.

- Further, even when a machine is capable of performing a task inexpensively, there may be a visible gap between the machine doing that task inexpensively and doing it well. Consider automated checkout lines at supermarkets and automated check-in lines at airports. Intelligent machine innovations such as these reduce supplier costs, but clearly can be the source of customer frustration and delays.

- The use of "big data" has the potential to diminish the need for human judgment and interpretation that currently cause some jobs to be resistant to automation. A range of cognitive tasks could be susceptible to machine learning and recognition if their development is based upon large data sets that are capable of recognizing patterns and therefore can capture the key aspects of human choice and behavior. Just as big data enable Amazon to suggest books that customers might like based on their internet behavior, these data sets also might inform activities ranging from selling automobiles, houses and tickets to serving legal clients and responding to calls for law enforcement.
- None of the studies directly addresses the distinction that some economists currently make between "tradable" versus "non-tradable" goods. Tradable goods are those that are sold internationally in competitive markets, for example, cellphones. In tradable markets, automobile workers in one country (say, the U.S.) can lose their jobs to automobile workers in another country (say, China) because of international competition. By contrast, goods and services in non-tradable markets are not subject to international competition. A hairstylist in Harrisonburg isn't in competition with a hairstylist in Beijing. Even so, things can change. Consider that tax preparation used to be a predominantly local industry – relatively few customers went outside of their hometowns to get their tax returns completed. However, because of automation, a tax preparer in Danville now can lose her job to tax preparers in New York City or Beijing who are using software and internet connections that enable them to prepare tax returns for residents in Southwest Virginia. The point is easily understood: Automation converts some goods and services from tradable to non-tradable and this can result in the loss or shuffling of jobs. This trend is likely to continue as software driven by artificial intelligence makes it possible for items such as tax forms to be completed anywhere.
- Frey and Osborne point out that many of the people who will lose their jobs as a result of automation are among those in society least able to cope with such disruptions due to background, education and lack of mobility. It seems likely, therefore, that the impact of automation will be felt unevenly across income classes.
- The analysts do not directly discuss current proposals, such as a $15 per hour minimum wage, but economic analysis predicts that such a law would provide an additional incentive for employers to accelerate the adoption of laborsaving automation. The salient questions are whether the nature of their production processes, their specific collective bargaining agreements and the law actually give them the flexibility to do so. The answers clearly differ across industries and even inside industries.

None of the analysts should be regarded as champions of the world they foresee. They are impartial reporters of the facts as they view them. Still, they note that the demise of high-risk jobs will increase unemployment at least in the short run and likely increase economic inequality as well unless society provides financial incentives and invests in job retraining programs designed to ease the flow of people from the high-risk occupations where jobs are being lost, to low-risk occupations where the number of jobs is increasing. Of course, this may be easier said than done. How does one teach creative and social skills, how to interpret and make judgments, and how to adjust to the unexpected to people who may have lower than average intellectual abilities and who for decades have been performing repetitive tasks? How does one convince an unemployed steelworker with a family and a mortgage that he or she should move from West Virginia to Texas? Frey and Osborne are straightforward: "For workers to win the race, however, they will have to acquire creative and social skills." This is important advice, given that McKinsey suggested in 2013 that sophisticated algorithms could substitute for approximately 140 million full-time knowledge workers worldwide.[2]

2 McKinsey Global Institute, "Disruptive Technologies: Advances That Will Transform Life, Business and the Global Economy."

# The National Picture

For the United States as a whole, Frey and Osborne estimate that 47 percent of all nonfarm jobs fall into their "high risk" category in terms of being eliminated because of automation. In April 2016, this would have translated to 67.64 million nonfarm jobs – a staggering number.[3] However, even if Frey and Osborne's estimates are precisely on the mark, it does not follow that these losses will occur immediately. Multiple decades sometimes are required for industries to adjust to new realities. Witness the slow deterioration of output levels and jobs in the coal, textile and tobacco industries in Virginia.

Graph 1 reports the five broad occupational categories that Frey and Osborne estimated have the greatest vulnerability to job losses because of technological change, plus the five broad occupations with the least susceptibility.

The McKinsey study approaches the job vulnerability question through a somewhat different lens by focusing on 2,000 different work activities in more than 800 occupations. Similar to the OECD, McKinsey argues that individual occupations are distinctive in requiring a variety of different work activities, which might include physical movement, processing data, interacting with customers and the like. These work activities have varying potential for automation. The McKinsey study provides estimates of the portion of time during each workweek that a typical worker spends on each specific work activity. Graph 2 reports the estimates of the percentage of time during a typical workweek that workers in the United States spend on various work activities. From left to right, these range from the work activities least susceptible to automation (such as managing others) to those most susceptible to automation (predictable physical work).

Miles Brundage of Slate asks an interesting question: In the future, will "made by humans" become a phrase equivalent to "organic" or "fair trade"? www.slate.com (Sept. 27, 2013)

3 This is a seasonally adjusted number and includes government employees.

Where physical work is concerned, it is the predictability of the motions involved with that work that is the key to the susceptibility of a particular occupation to automation. McKinsey concluded that 78 percent of jobs involving predictable physical work (welding, food preparation and packaging of products) are prone to be automated, whereas only 25 percent of jobs involving less predictable physical work (construction, forestry and raising outdoor animals) are vulnerable. Using the same analysis, McKinsey concluded that 47 percent of a retail salesperson's activities have the technical potential to be automated, but fully 86 percent of the jobs of the retail sector's bookkeepers, accountants and auditing clerks are in jeopardy. McKinsey reported these estimates in detail in a 2015 study.[4] The consulting group concluded that 45 percent of all work activities could be automated using already available technologies, but only 5 percent of all occupations (the Frey and Osborne focus indicator).

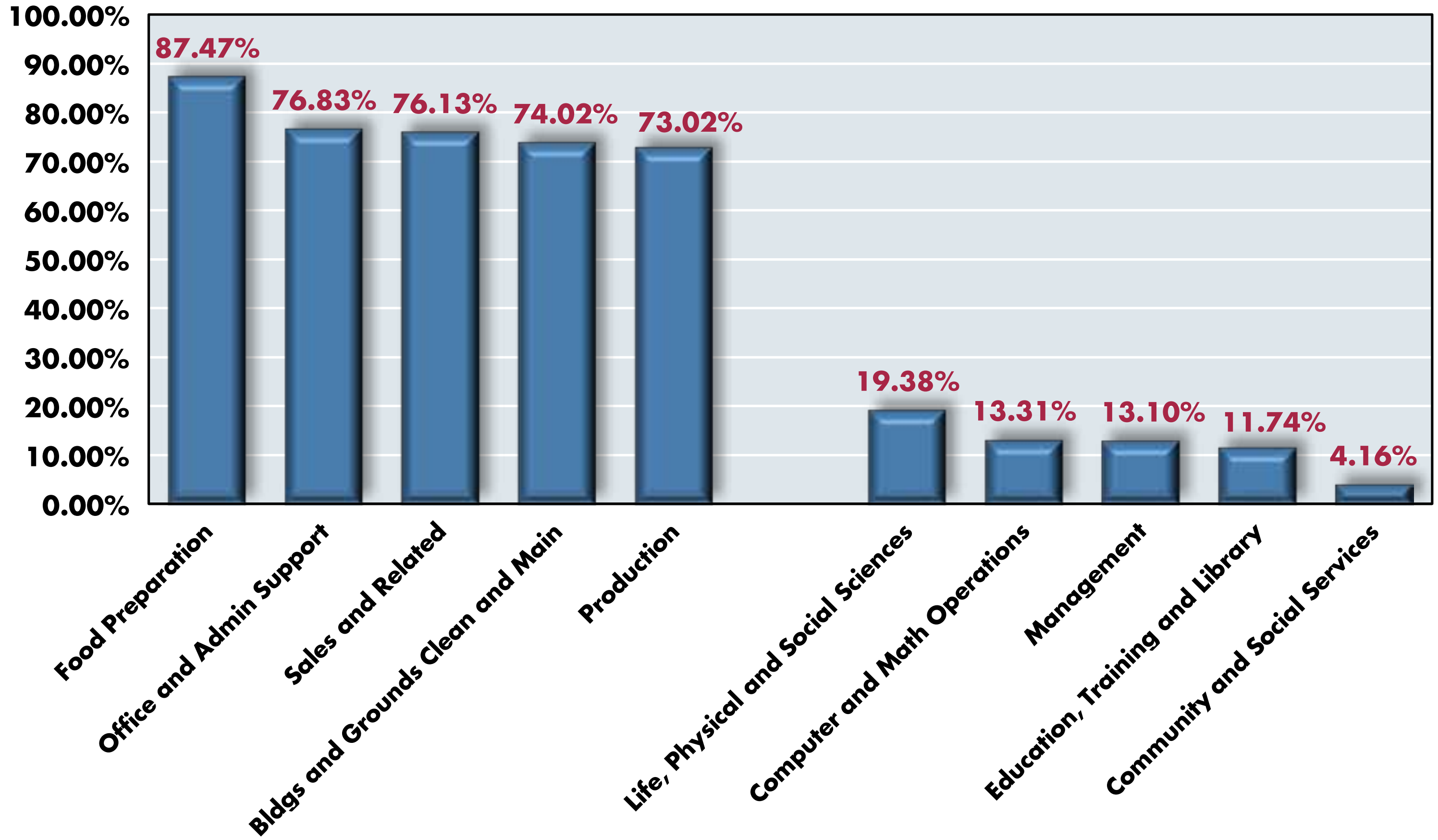
The McKinsey analysts also estimated that more than 20 percent of a typical CEO's working time could be automated using currently available technologies. The analysts concluded that several lower-paid occupations, such as health aides, landscapers and maintenance workers, faced fewer risks associated with automation because the work of the individuals in these occupations could not easily be replaced by a machine or replicated by means of AI.

The consulting group found that the amount of workers' average hourly wages explained only 19 percent of the variability in their automation susceptibility. That is, it was the characteristics of specific work tasks rather than the monetary value of that work that was the most important determinant of whether or not those work tasks were vulnerable to automation. High salaries did not guarantee reduced susceptibility to automation. Indeed, the opposite may be true – high salaries increase the incentive for employers to seek ways to automate.

4 Michael Chui, James Manyika and Mehdi Miremadi, "Four Fundamentals of Workplace Automation," www.mckinsey.com/business-functions/business-technology/our-insights/four-fundamentals-of-workplace-automation (November 2015).

**GRAPH 1**

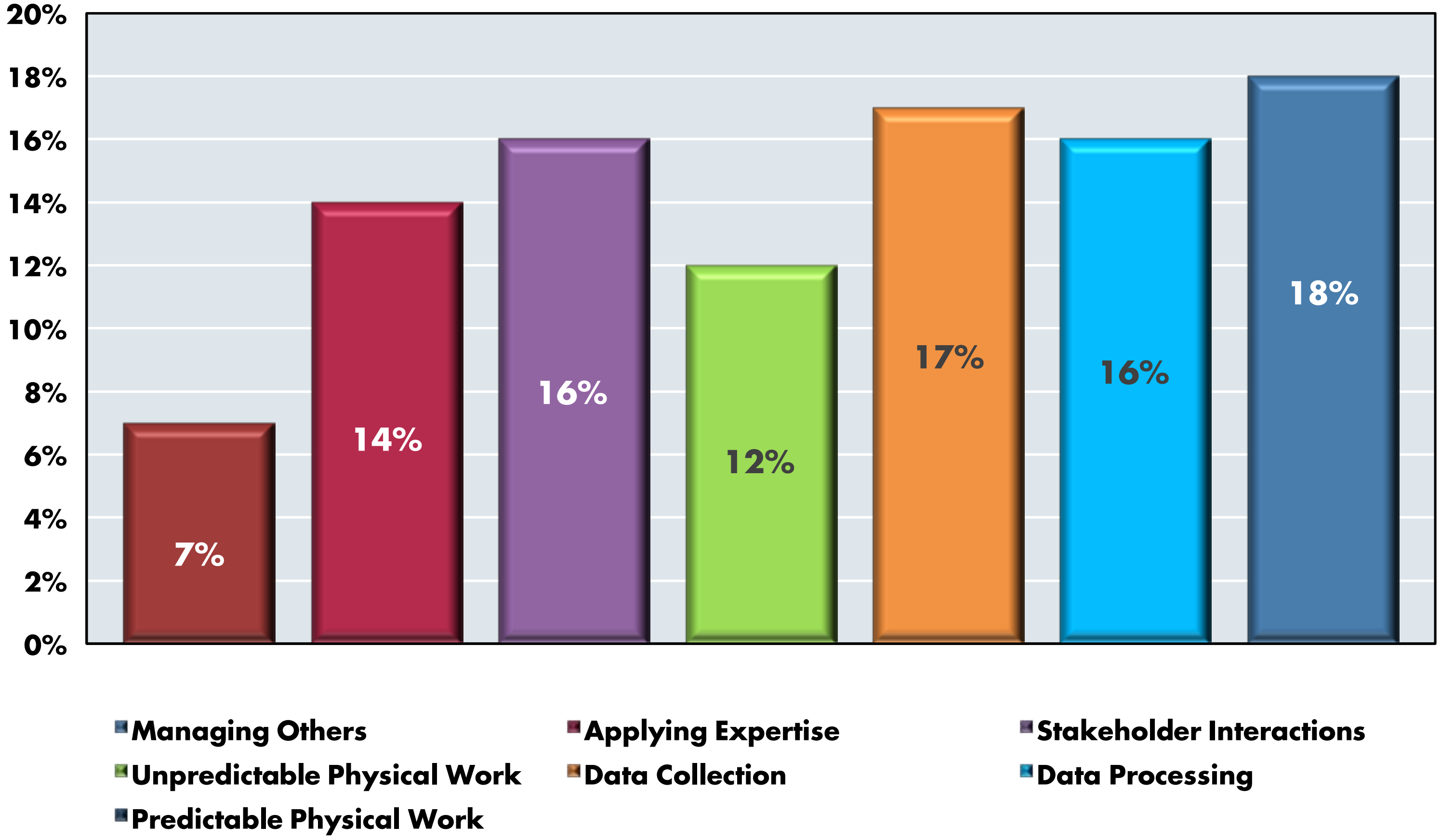
**THE BROAD OCCUPATIONS MOST (LEAST) SUSCEPTIBLE TO AUTOMATION: PERCENT OF JOBS IN FREY AND OSBORNE'S "HIGH RISK" CATEGORY**




Source: Carl Benedikt Frey and Michael A. Osborne, "The Future of Employment: How Susceptible Are Jobs to Computerisation?" Oxford University Martin School, Sept. 17, 2013

**GRAPH 2**

**PERCENT OF TIME SPENT IN VARIOUS WORK ACTIVITIES IN ALL U.S. OCCUPATIONS, 2014**




Source: Michael Chui, James Manyika and Mehdi Miremadi ("Where Machines Could Replace Humans – and Where They Can't (Yet)," www.mckinsey.com/business-functions/business-technology/our-insights/where-machines-could-replace-humans-and-where-they-cant-yet?cid=other-eml-alt-mkq-mck-oth-1607), July 2016

# The Virginia Picture

Frey and Osborne examined 702 specific occupations as defined by the Bureau of Labor Statistics and ultimately assigned a probability to each occupation that is their estimate of the susceptibility of the jobs in that occupation to disappearing because of automation. Let's begin our analysis by applying their technique to 22 broad occupational labor force segments in Virginia. Table 1 supplies these data, which apply to 3,682,470 Virginia nonfarm workers in 2015 in the Commonwealth.

It is evident in Table 1 that Frey and Osborne's methodology suggests that 1,877,540 jobs in Virginia are susceptible to automation whereby a machine, software or artificial intelligence replaces the worker. This is 51 percent of all Virginia jobs (compared to the national average of 47 percent) and these jobs account for $70.56 billion in annual wages. Note that Virginia's total employment roster is slightly more vulnerable to technological change than is true for the United States. This implies that Virginia's workforce has a lower percentage of workers performing nonrepetitive tasks that require judgment and on-the-job flexibility.

That one's job is susceptible to being lost to technological change does not mean that this actually will occur. Not all employers choose to automate, or to do it in the same ways. Further, some work tasks that appear to be highly repetitive sometimes turn out not to be so at crucial decision points in the work process and therefore resist "pattern recognition" – the application of artificial intelligence in a manner that adequately imitates what a human being would do in a specific situation. A manufacturing robot, for example, might be superb at detecting minute differences in the size and weight of items being produced, but nevertheless be unable to detect emerging differences in smell or color. Human participation and intervention still are required in some situations.

Frey and Osborne are not inerrant savants who can see around corners and neither are we. They note that "making predictions about technological progress is notoriously difficult" and acknowledge that some occupations will experience future tumult from automation that they currently do not predict. For example, one should not read the numbers in Table 1 to mean that it is a certainty that more than 278,000 jobs relating to food preparation absolutely are going to be lost in Virginia. Additionally, as noted previously, even if these job losses do occur, decades may be required for this to happen.

**In general, we can see in Table 1 that there is a tendency for the negative job impacts of technological change to land most heavily on the least-educated members of the labor force – but only if their jobs involve the repetitive, absence of judgment characteristics mentioned previously. The key to surviving automation is not worker education, per se, but instead job characteristics involving varied tasks that require workers to make judgment calls, on occasion to use their intuition and in some cases to work together as a team.**

Note that if the OECD study referenced earlier is correct, then the number of Virginia jobs at risk is not 1,877,540, but rather only 327,822 – still a large number, but one that would be much more manageable. The OECD critique of Frey and Osborne's work focuses on the variability in the occupational circumstances and conditions the OECD believes exist inside the 702 occupations that Frey and Osborne analyze. This variability, the OECD argues, means that it often is inappropriate to include all jobs in an occupation in a category labeled "at risk."

No doubt some variability in job activities and requirements does exist inside conventionally labeled occupations; however, 702 distinct occupations is a large number and separate analysis of each occupation at this level of detail likely picks up considerable heterogeneity in worker tasks. Nonetheless, the OECD analysis underlines that the most expansive estimates of the impact of automation on jobs should be inspected carefully and probably deflated. Further, even if 47 percent of all jobs in the United States are at risk because of automation, it does not follow that the loss of these jobs would occur immediately. Decades might be required for such an adjustment to occur. The slow, downward employment evolution of the automobile, coal and steel industries in the United States illustrates the often-gradual nature of occupational and industrial change.

**TABLE 1**

**FREY AND OSBORNE'S SUSCEPTIBILITY TO AUTOMATION TECHNIQUE APPLIED TO 22 BROAD JOB CLASSIFICATIONS: VIRGINIA, 2015**

| BROAD OCCUPATIONAL GROUP | VIRGINIA TOTAL EMPLOYMENT | AVERAGE HOURLY WAGE | AVERAGE ANNUAL INCOME | TOTAL VIRGINIA ANNUAL WAGES | PERCENT JOBS AT RISK | TOTAL JOBS AT RISK | TOTAL ANNUAL WAGES AT RISK |
|---|---|---|---|---|---|---|---|
| Management Occupations | 166,610 | $ 61.79 | $ 128,530 | $ 21,414,383,300 | 13.10% | 21,826 | $ 2,606,680,168 |
| Business and Financial Operations Occupations | 251,780 | $ 39.24 | $ 81,620 | $ 20,550,283,600 | 43.37% | 109,197 | $ 8,561,241,991 |
| Computer and Mathematical Occupations | 195,140 | $ 46.52 | $ 96,750 | $ 18,879,795,000 | 13.31% | 25,973 | $ 2,020,223,511 |
| Architecture and Engineering Occupations | 73,790 | $ 41.31 | $ 85,930 | $ 6,340,774,700 | 21.15% | 15,607 | $ 985,125,516 |
| Life, Physical and Social Science Occupations | 31,160 | $ 39.76 | $ 82,700 | $ 2,576,932,000 | 19.38% | 6,039 | $ 414,754,154 |
| Community and Social Service Occupations | 50,870 | $ 22.91 | $ 47,660 | $ 2,424,464,200 | 4.16% | 2,116 | $ 86,907,634 |
| Legal Occupations | 36,050 | $ 49.75 | $ 103,480 | $ 3,730,454,000 | 27.53% | 9,925 | $ 565,249,295 |
| Education, Training and Library Occupations | 237,250 | $ 25.93 | $ 53,930 | $ 12,794,892,500 | 11.74% | 27,853 | $ 1,051,500,158 |
| Arts, Design, Entertainment, Sports and Media Occupations | 48,510 | $ 27.51 | $ 57,220 | $ 2,775,742,200 | 17.85% | 8,659 | $ 531,050,098 |
| Healthcare Practitioners and Technical Occupations | 198,840 | $ 36.24 | $ 75,390 | $ 14,990,547,600 | 14.30% | 28,434 | $ 1,366,670,286 |
| Healthcare Support Occupations | 85,840 | $ 14.00 | $ 29,120 | $ 2,499,660,800 | 23.70% | 20,344 | $ 625,569,235 |
| Protective Service Occupations | 99,650 | $ 21.41 | $ 44,530 | $ 4,437,414,500 | 44.31% | 44,155 | $ 1,604,686,868 |
| Food Preparation and Serving Related Occupations | 318,730 | $ 11.00 | $ 22,870 | $ 7,289,355,100 | 87.47% | 278,793 | $ 6,239,845,855 |

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|---|---|---|---|---|---|---|---|
| Building and Grounds Cleaning and Maintenance Occupations | 124,970 | $ 12.21 | $ 25,400 | $ 3,174,238,000 | 74.02% | 92,503 | $ 2,369,839,041 |
| Personal Care and Service Occupations | 119,900 | $ 12.47 | $ 25,930 | $ 3,109,007,000 | 41.06% | 49,231 | $ 1,057,000,959 |
| Sales and Related Occupations | 392,330 | $ 18.61 | $ 38,710 | $ 15,187,094,300 | 76.13% | 298,681 | $ 9,298,746,336 |
| Office and Administrative Support Occupations | 549,560 | $ 17.58 | $ 36,570 | $ 20,097,409,200 | 76.83% | 422,227 | $ 14,749,877,695 |
| Farming, Fishing and Forestry Occupations | 6,380 | $ 15.77 | $ 32,800 | $ 209,264,000 | 41.54% | 2,650 | $ 100,689,765 |
| Construction and Extraction Occupations | 156,160 | $ 20.36 | $ 42,360 | $ 6,614,937,600 | 61.58% | 96,163 | $ 3,743,489,693 |
| Installation, Maintenance and Repair Occupations | 144,650 | $ 22.65 | $ 47,110 | $ 6,814,461,500 | 56.94% | 82,364 | $ 3,649,015,736 |
| Production Occupations | 171,550 | $ 17.51 | $ 36,420 | $ 6,247,851,000 | 73.82% | 126,638 | $ 4,328,941,847 |
| Transportation and Material Moving Occupations | 222,750 | $ 17.41 | $ 36,220 | $ 8,068,005,000 | 63.05% | 108,162 | $ 4,606,862,311 |
| Totals | 3,682,470 | | | $ 190,226,967,100 | 50.99% | 1,877,540 | $ 70,563,968,152 |

Source: May 2015 Occupational Employment Statistics (OES) data are available from the Bureau of Labor Statistics, www.bls.gov/oes/tables.htm. The May 2015 area level estimates are the first OES estimates to use the 2010 metropolitan statistical area definitions.

# Is Technological Change (And Job Churning) Speeding Up?

Is the job-churning process identified by Frey and Osborne going to accelerate? That is the trillion-dollar question. It's true that nearly everywhere we look, there is evidence of technological change: self-driving automobiles and intelligent tractors, smartphones with amazing capabilities, potent new drugs, cloud computing, disease-resistant crops, medical therapies tailored to a specific individual's genetic makeup. The list of technological changes is impressively long and some argue that this lends credence to futurist Ray Kurzweil's 2001 prediction: "We won't experience 100 years of progress in the 21st century – it will be more like 20,000 years of progress (at today's rate)."[5] The implication is that technological change is going to cut a wide swath through global labor forces in the coming decades.

Perhaps, but there are others who point out that for all of the marvelous technological innovations that have occurred in recent years, actual productivity increases have been disappointingly small. As George Mason University economist Tyler Cowen put it, "Silicon Valley has not saved us from a productivity slowdown" (*The New York Times*, March 4, 2016). The fundamental economics is simple: If technological innovations do not lead to significant increases in productivity, then this seriously diminishes their lure. Why invest in equipment, software enhancements or AI unless such investments are really going to make a difference?

Graph 3 reports the average annual growth in labor productivity (literally, output per worker hour) in the United States over the past 20 years. One can see that since 2009, labor productivity growth has stalled and now is clearly on a lower trend line than it was in the previous decade. This reduces the incentive for decision makers to invest in new technologies that hold little promise of improving the firm's bottom line.

Economic data leave little doubt that there has been a slowdown in productivity growth that actually dates back to about 1970. Some label this "secular stagnation," but whatever its label, it has afflicted nearly all mature Western economies that have not been sitting on substantial oil deposits. Some highly reputable analysts, such as Northwestern University's Robert Gordon, argue that recent decades have been characterized by a dearth of truly consequential, cost-reducing, production-increasing innovations ("The Rise and Fall of American Growth," Princeton University Press, 2015).

Nevertheless, even if productivity were not declining, reality is that a significant proportion of recent innovations have been *labor-saving* in nature – apparent advances that cause firms and organizations to substitute machines and AI for people. Consider that in 2015, the United States produced 21.3 percent more manufactured output, but accomplished this with 16 percent fewer workers than in 2001.[6] Further, this and similar episodes of automation often generate ripples of change throughout the economy. As self-driving cars and trucks move into the mainstream, the jobs of mechanics, insurance agents, car salespersons and repair shop workers will be disrupted, and some of them no doubt will lose their jobs.

**In the long run, society as a whole emerges better off and enjoys a higher standard of living when such developments occur because these innovations free up workers who subsequently can be employed doing other things. Remember that in 1800, approximately 90 percent of the labor force in the United States was involved in agriculture. Today, less than 2 percent of our labor force is so occupied, but that 2 percent is marvelously productive. The remaining 98 percent of the labor force is employed doing other things that have resulted in dramatic growth in our standard of living.[7]**

**The short-run story, however, can be painfully different.** Workers displaced by technological innovations lose their jobs and subsequently

5 http://www.kurzweilai.net/the-law-of-accelerating-returns. Kurzweil and others speak of "singularity," a situation in which technological change has become so rapid and so profound that it disrupts, perhaps even destroys, human life as we know it. In this view, technological change is a double-edged sword that simultaneously generates benefits, such as longer life spans and reduced physical drudgery, even while it introduces significant new dangers that range from the obvious (nuclear bombs) to less-obvious AI innovations and nanobots that are controlled by unscrupulous forces, perhaps even other, nonhuman AI software.

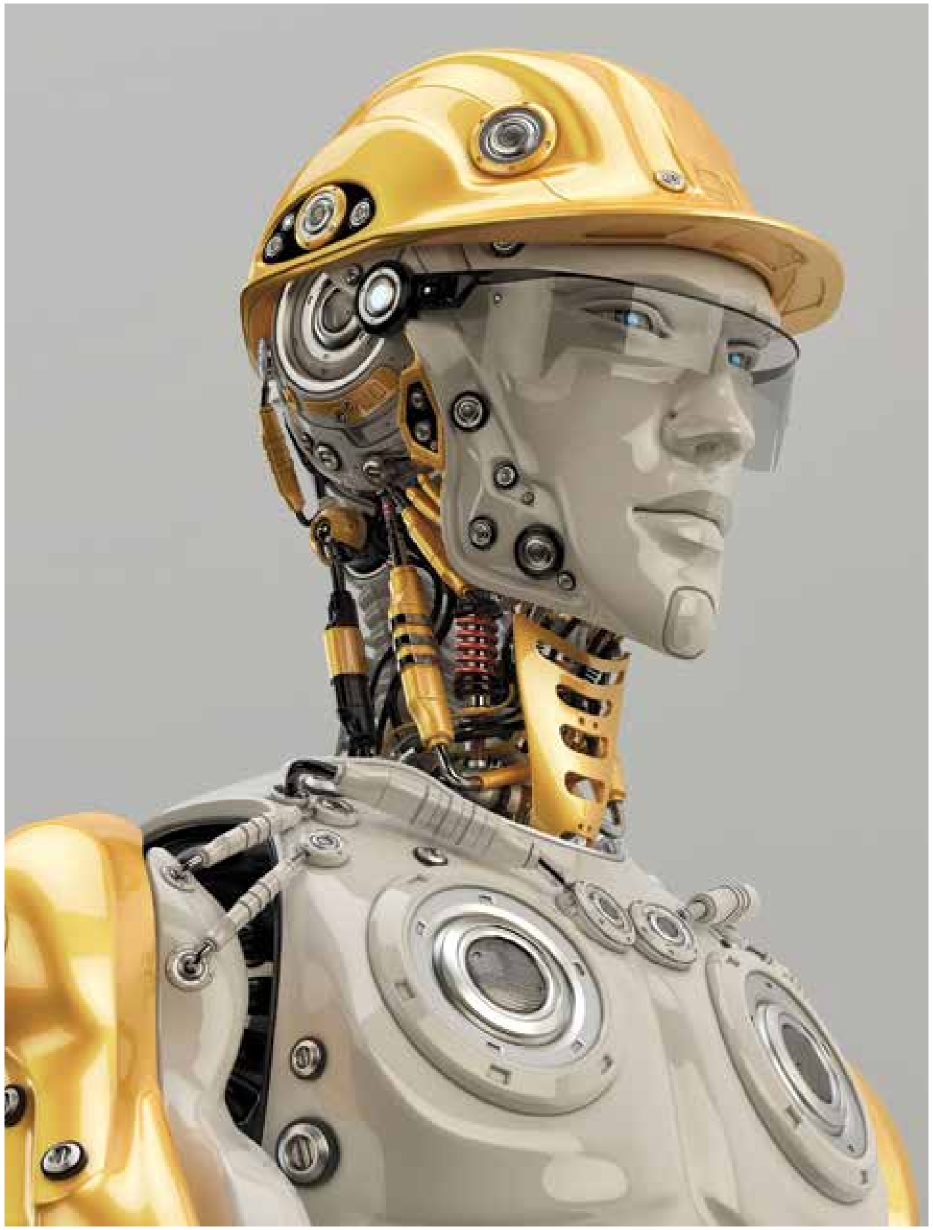
6 Old Dominion University calculations based upon U.S. Department of Commerce data and the North American Industry Classification System (NAICS).

7 In the jargon of economics, such innovations push out society's production possibilities curve and make it possible for society to improve its standard of living.

may find it difficult to obtain new employment. In some cases, this is because they are not qualified for the jobs that are available – they are the proverbial square pegs attempting to fit into round holes. Jobs exist for welders, but steelworkers who have lost their jobs are not trained to weld.

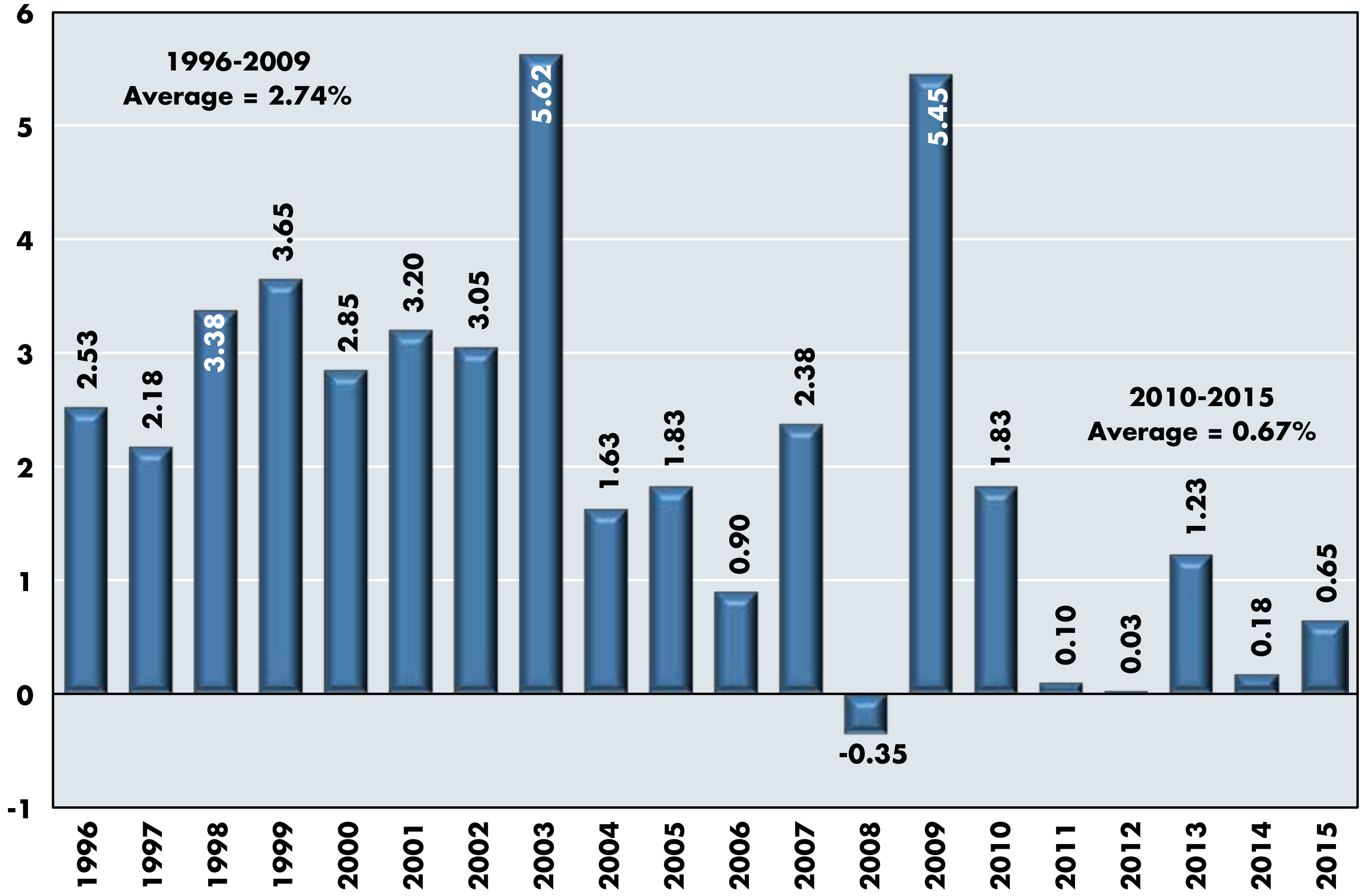
It is these “susceptible” individuals/workers whose circumstances are highlighted by Frey and Osborne. Not only may some of them lose their jobs, but also their spell of unemployment could turn out to be disappointingly long because they are not qualified to fill available job openings. They also could be both emotionally and geographically immobile. Or, the economy could be in the midst of recession and employers simply don’t need additional workers. Whatever the reason, they are the “at risk” employees in today’s economy.

While we sometimes hear alarmist rhetoric about job-destroying new technologies, the available data do not really support this interpretation. Graph 4 reports the absolute number of job layoffs and discharges by month in the United States between 2000 and 2016. Immediately visible is the upward spike in layoffs and discharges produced by the Great Recession. Other than this, since 2011, monthly levels of layoffs and discharges in the United States now are lower than they were at the turn of the century. It’s not clear that changes in technology, whether accelerating or not, have resulted in huge numbers of displaced workers who have lost their jobs to machines, software or AI.



**GRAPH 3**

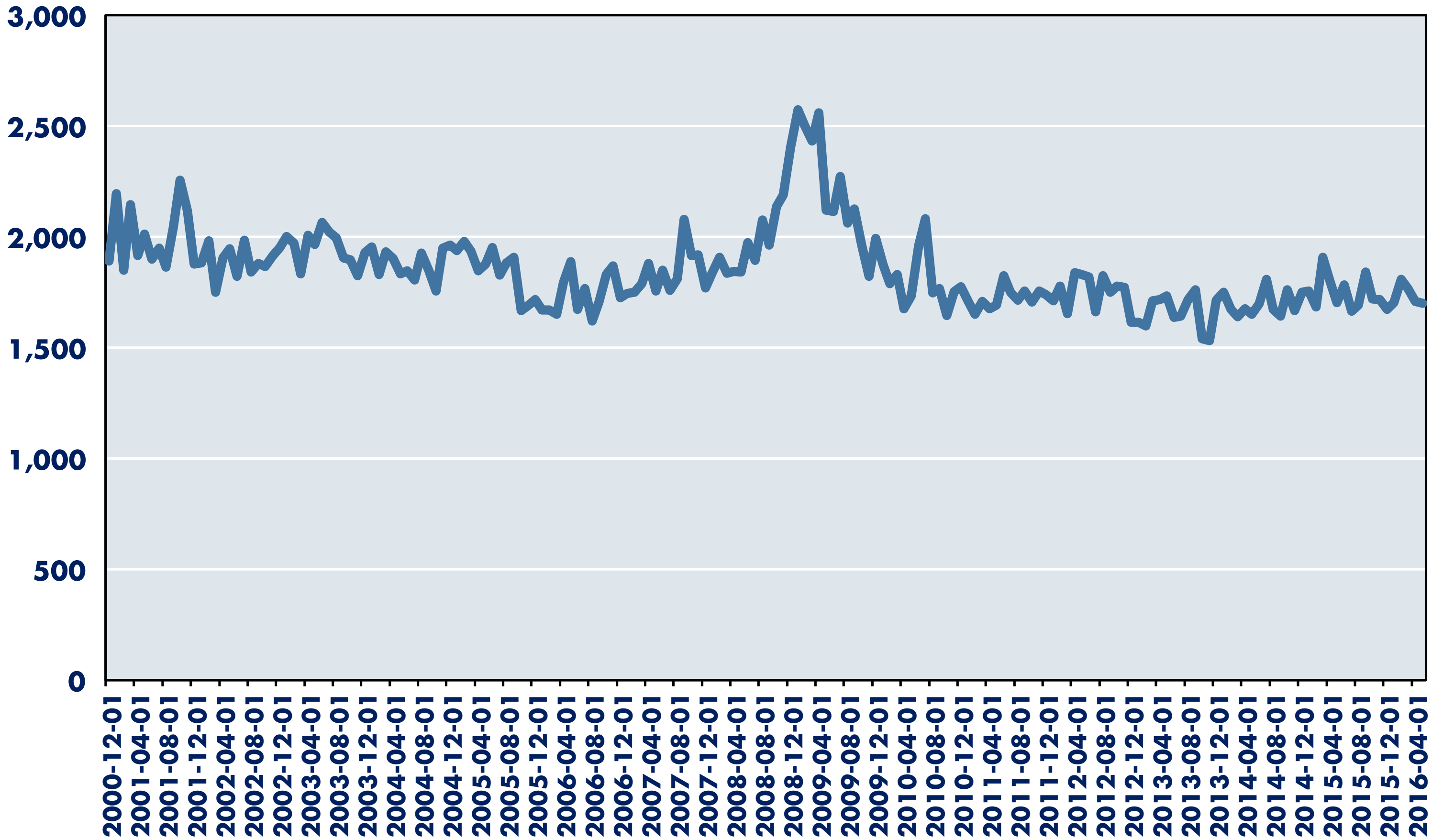
**ANNUAL PERCENT GROWTH IN LABOR PRODUCTIVITY (OUTPUT PER HOUR) IN THE UNITED STATES, 1996-2015**




Source: Bureau of Labor Statistics, Series ID PRS85006092

**GRAPH 4**

**NUMBER OF JOB LAYOFFS AND DISCHARGES BY MONTH: UNITED STATES, 2000-2016**




Source: FRED database, https://research.stlouisfed.org/fred2/series/JTSLDL. Data are seasonally adjusted.

# Implications

When technological change occurs, it often results in some workers losing their jobs and increased levels of economic inequality. Predictably, labor unions and worker advocates (some political) often resist such adjustments and demand that generous benefits be paid to those affected and that extensive job retraining programs and educational alternatives be offered at very low personal cost to each displaced worker. Similar arguments are made when freely flowing international trade causes workers to lose their jobs. One can make a credible equity case for supplying such benefits and programs to displaced workers even though the available economic evidence discourages the notion that there are conspicuous skill shortages (even in STEM-related occupations)[8] in American labor markets and the rates of return realized by governments that finance job retraining programs often are mediocre.

A dynamic, growing economy requires willingness on the part of firms and organizations (including governments) to accept and implement cost-effective new methods of production and service. **In response, wise public policies in this arena should focus on "riding the wave" of technological change rather than encouraging resistance movements that are destined to prove futile. Astutely constructed public-private partnerships between governments and firms have the potential to develop programs designed to compensate and redirect job losers, who in many cases are relatively innocent victims of dynamic economic forces well beyond their control.**

**Three classes of programs commend themselves. These involve increasing the skills, flexibility and mobility of the workforce.** With respect to skills, policy focus should be upon proficiencies that count in modern labor markets. This is not the same thing as generating massive numbers of additional bachelor's degree holders, or STEM-degree holders, though many elected officials make this a high priority. To the surprise of many casual observers, there is relatively little rigorous economic evidence available that a significant shortage of job candidates exists in STEM-related occupations. Examples of skills currently in demand include computer coding, welding and a wide variety of tasks associated with health care. The recent emphasis on "credentialing" may provide a means for individuals to upgrade their qualifications and abilities without committing themselves to entire academic degree programs.

With respect to flexibility, wherever possible, education and training should emphasize suppleness in thinking and approach, rather than rote memory. As Fareed Zakaria of The Washington Post (March 26, 2015) put it so succinctly, "Critical thinking is, in the end, the only way to protect American jobs." Occupational shortages come and go, often in unpredictable sequences. Workers now stay with the same employer for a median of only 4.6 years.[9] The days of virtually guaranteed, steady employment with the same firm are all but gone. Like it or not, flexibility on the part of both employers and employees is the key to success.

With respect to mobility, wise public policy will reduce barriers that discourage people from moving geographically and/or telecommuting to jobs that may be located thousands of miles away.

Relatively little in this domain will occur either easily or without controversy; witness recent discussions surrounding disrupters Uber and Lyft. What the available empirical evidence does tell us, however, is that the current range of public policies is insufficient to deal with the occupational ferment that Frey and Osborne have identified. We are forewarned.

8 See Peter H. Cappelli, "Skills Gaps, Skill Shortages, and Skill Mismatches: Evidence and Arguments for the United States," *Industrial and Labor Relations Review*, 68 (March 2015), 251-90.

9 Bureau of Labor Statistics, www.bls.gov/news.release/pdf/tenure.pdf.