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# Automation and the Labor Force

Loren Nerhus

**ABSTRACT.** Technological progress has been the catalyst behind the increases in living standards across time. One aspect of technological progress is automation. Automation, more than other technologies, has significant effects on the labor force. From World War II until now, routine tasks have largely been automated. Perceptive tasks have belonged mainly to the domain of human labor until very recent innovations. These innovations may change the labor force, as new employment opportunities will not replace jobs as quickly as the old ones are automated.

The number of labor hours needed to produce the goods in the U.S. economy will soon decrease significantly. This has both short-term and long-term implications. In the short-term, those with the right skills will benefit financially, while those with the wrong skills will not reap this bountiful harvest. In response to this, it is imperative to continually educate society to match skills with the level of technology. In the long-term, it is theoretically possible to automate all of human labor. If that occurs, then the economic problem would be solved, and resources could be distributed equally.

## I. Introduction

“A car that is able to see, to calculate, to think, and can respond to what it encounters. Even if that means completely stopping itself. It’s the stuff of science fiction--minus the fiction. The 2014 E-class, the most intelligent E-class ever.”

-2014 Mercedes-Benz E-Class Advertisement

Humans’ ability to see, calculate, think, and respond is what makes them able to perform many tasks better than anything else. Now humans make machines, such as the new Mercedes-Benz car, that have perceptive abilities similar to humans. This advancement is changing the structure of human labor. The change is tremendously beneficial, but also contains downsides that need to be addressed. One possible conclusion after an inspection of the evidence is that aggregate labor hours will decrease in the future, even if aggregate demand increases. As this happens, society should renew its emphasis on education. This may seem like futuristic science fiction, but as the advertisement claims, these scientific ideas are taking shape sooner than once thought. As they do, the economic landscape will change with it.

## **II. Technological Advancement and Creative Destruction**

Improvements in technology drive the increase in living standard in a society (Sachs and McArthur 2002, 157). The United States is currently the world leader in technological advancement as a consequence of an extensive patent system that correctly rewards those who create valuable products (Sachs and McArthur 2002, 168). These innovations make work less taxing, living conditions more comfortable, and health care more extensive. Even though everyone in society benefits from improvements in technology, it does create negative externalities for some segments in the short run.

For example, when the assembly line was introduced, it caused unemployment for the craftsmen and artisans who made the product from start to finish. The technological improvement, the assembly line, created more value for society, but destroyed jobs for some. This phenomena is known as creative destruction. Creative destruction is the natural consequence of an innovation (Frey and Osborne 2013, 5-6). This makes jobs and business models obsolete. In the long-run, however, even workers whose professions are taken away by new technology are gainfully employed (Sachs and McArthur 2002, 158). Historically, the benefits of technological improvements are spread throughout most of society. The Industrial Revolution is an example of how this occurs (Frey and Osborne 2013, 7).

Automation is the newest technological revolution. Automated machines are now taking over jobs previously done by humans. Continuing with the example from above, workers on the assembly line are replaced by machines that make the product from start to finish.

In the past, the bulk of the population moved up in real income when new industries were created. From 1969-1999, however, the blue-collar workforce in the US dropped from 56 percent of the population to 39 percent of the population (Levy and Murnane 2004, 41). Service workers, typically associated with low skills and low pay, increased by 2.3 percentage points. On the other hand, sales, technicians, professionals, and managers also grew modestly as a percentage of the labor force. These segments of the economy are usually associated with higher pay and more training. Overall during this time period, real living conditions increased as a society. Creative Destruction, however, created some “losers” in the market place (Levy and Murnane 2004, 35-36).

Human labor is changing with technology. It is important to know

how it is changing and what society can do to best adapt to the new environment. Creative Destruction shows that there are downsides for the economy due to increases in automation. Sachs and MacArthur show that nations that innovate have the highest income and are better off than the rest of the world. The second tier of nations that adapt the technology quickly have rising income, but still significantly trail the innovators. If a country neither innovates nor adapts well, it is left behind in poverty. “The top 20 patenting countries in the world, with less than 15% of the world’s population and 77% of its GNP, account for 99% of all the patenting in the U.S.” (Sachs and McArthur 2002, 166). This clearly shows an advantage for technological innovators. It is important to see how this innovation is coming about, as well as how the US labor market will change because of it. As the labor market changes, educational and social changes will occur with it.

Human-labor tasks can be separated into five broad categories. Listing them least valued financially to most, in general, they are service tasks, routine mental, routine physical, complex communication, and expert thinking (Levy and Murnane 2004, 47-48). Separating the labor force into five broad task categories might produce confusion. One specific job might employ all of these skills, and most use at least two of them. A plumber, for instance, does all five. He completes a service task by communicating with a concerned human and assuring that the problem can be fixed. He uses expert thinking to identify patterns in physical places that are different in each house, and identifies the problem. Once the problem is identified, he uses routine mental and physical processes to fix the specific problem.

The categorization of each task is not always applicable. This certainly creates a limitation, but these categories can provide a structured framework to analyze automation more effectively.

### **III. Automation Defined**

Automation is an “automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor” (Merriam-Webster). There are two subsets within automation.

One subset is logic-based automation, which employs “if, then, do” statements to complete tasks (Levy and Murnane 2004, 57-58). In human terms, these are routine tasks. Manufacturing is the essence of the routine

physical task. Routine mental tasks vary greatly. Some examples are fraud detection, loan approval, and a bank teller. Search engines respond to routine queries using linear deduction (Frey and Osborne 2013, 16). Personal computers easily automate routine mental tasks, while industrial machines automate routine physical tasks. The comparative advantage tips in the direction of automation for logic-based tasks. This is why blue collar workers have seen a substantial decrease as a share of the population, and will continue to as time moves forward.

The other subset of automation is perception. Humans are masters at both physical and mental perception, and it is a challenge to program a machine to do the same (Brynjolfsson and McAfee 2012, 12-14). Perceptive tasks include service skills, complex communication, and expert thinking. These broad tasks are more prevalent in the US labor market, as routine automation has taken shape in recent years.

Levy and Murnane assumed that these jobs would not be automated (Brynjolfsson and McAfee 2012, 12-14). Until recently, it was reasonable to assume that only easily programmable, routine jobs would be automated. Recent advances in automation cast doubt upon this assumption (Frey and Osborne 2013, 3). Before delving into how these recent technologies will change the labor market of the future, it is necessary to establish how the labor market has changed up until now through automation.

#### **IV. Past and Present Analysis—Routine Automation**

##### **A. BENEFITS**

As was outlined previously, technological changes make work less difficult and improve living standards. Computers are the driving force behind automating routine mental tasks. The U.S. economy has benefited from the increase in the use of computers. Some of these routine mental tasks were not even conceivable beforehand. Some computations that computers do are impossible by hand. The share of economic growth attributable to computers has increased over time (Jorgenson and Stiroh 2000, 126-127). Average Labor Productivity grew immensely in the 1990's, mostly due to advances in information technology. Information technology is an automated transportation of information. "The diffusion of IT improves business practices, generates spillover benefits, and raises productivity throughout the economy" (Jorgenson and Stiroh 2000, 126-

127).

IT was the basis for the large increases in productivity in the 90's as well as into the 21st century. In fact, labor productivity grew at an average of 2.5% per year from 2000-2009, besting every decade since the 1960's (Brynjolfsson and McAfee 2012, 30). This is surprising, given the economic downturn that the economy experienced at the beginning and end of that decade. The labor productivity growth is consistent with Moore's law, which says hardware processors will double in effectiveness every eighteen months (Brynjolfsson and McAfee 2012, 17-18).

The US economy has also seen the automation of routine physical tasks, which has increased profits for firms. It has increased the demand for complex communication skills for managers. Prior to automation, managers would give direct orders to their employees, and expected silent obedience in return. Consider the assembly line example. If someone could give clear directions on how to place the windshield into a car, he would be a good manager. Each task needed clear directions. The communication was not complex, merely "if, then, do" directions. Some of these tasks have been automated over time. Managers now communicate to their workers in a more understanding way, needing to listen and perceive as well as communicate clearly, instead of only the latter (Levy and Murnane 2004, 93-94). This demonstrates that the demand for complex communication has increased, while the demand for low-skilled manual tasks has decreased.

As outlined above, routine automation along with technological improvements have caused a skill-biased technical change. Skill-biased technical change is the change in the demand for workers. The demand for higher skills has increased in recent decades, causing the income of those individuals with marketable skills to rise (Autor, Katz, and Krueger 1998, 1169). As monotonous tasks are automated, more complex tasks require more education. "...the relative demand for more-skilled workers grew more rapidly during the past 26 years (1970-1996) than during the previous three decades (1940-1970)" (Autor, Katz, and Krueger 1998, 1171). There is a strong correlation between the "relative utilization of more-skilled workers" and the use of new technologies across and within industries (Autor, Katz, and Krueger 1998, 1171). Nearly every sector of the economy has experienced this shift. As the demand for these workers has grown, the supply has grown in step. US culture has changed in its assessment of what an adequate educational attainment should be. This attitude change is the supply curve shift to meet the demand shift, as

Americans have chosen more education levels each successive decade since World War II (Fernald and Jones 2014, 5).

## B. COSTS

Levy and Murnane point out that the unskilled jobs of the past have been replaced by skilled positions. Those with fewer skills, however, no longer have middle-class jobs and must accept lower-income jobs. Aside from the recent recession and its aftermath, employment opportunities have changed with the advent of automation. Even though routine jobs have been replaced by machines, non-routine employment opportunities have not been replaced. Indeed, they have grown. The problem is the increase in low-paying service jobs (Autor, Katz, and Krueger 1998, 1173-1181). "... among the least educated and lowest paid categories of employment, the share of US labor hours in service occupations grew by 30 percent between 1980 and 2005 after having been flat or declining in the three prior decades" (Autor and Dorn 2013, 1555).

Rising inequality in the United States has been the subject of much debate recently (Mankiw 2013, 21-34). Part of this rising inequality has to do with the divergence of labor demand, according to most experts (Autor, Katz, and Krueger 1998, 1169). This is not to say that the income inequality increase is only due to automation-driven labor change, but that it is a contributing factor. The most compelling evidence is an analysis of within-industry labor dynamics. Industries that have the largest technological share also have the largest contribution to skill-biased change.

Ed Wolff argues that the top 20% of the current income distribution received all of the benefits of the growth in the economy from 1983-2009. The bottom 80% actually saw a net decrease in wealth (Brynjolfsson and McAfee 2012, 34). This indicates a shrinking middle class. Automation is one explanation as to why this is occurring. Again, as routine tasks are automated, demand increases for higher skills, and blue collar workers either acquire the technological skills required, or are relegated to lower-paying service jobs. In contrast to what was said earlier about general technological advancement, it now seems that only some of the population directly benefit. In general, previous technologies supplement human labor, whereas automation replaces human labor.

Another theory is the outsourcing of jobs. Because the United States has an open economy, firms outsource jobs to places with cheaper labor.

The cheaper labor produces the same product at a fraction of the wage of a middle class American. It is popular for politicians and media to blame outsourcing for many US labor problems. Mitt Romney famously told the “lie of the year” in 2012, claiming that Chrysler was planning to move Jeep production to China (Adair 2013). The statement was based on some truth, and the general concern holds merit. There has been an outsourcing of call-centers to India, which has run parallel with the automation of other call centers (Levy and Murnane 2004, 84). Closer to home, Newton’s Maytag outsourced all of its jobs in Iowa, mostly to Mexico (Margolis and Mullins 2011). These examples contribute to the shrinking blue-collar workforce. Certainly, there are other reasons that may contribute to the widening gap between rich and poor, but the point of this section was to narrow down most of the explanation to these two theories.

## **V. Future Automation—Perceptive Tasks**

### **A. RECENT DEVELOPMENTS**

It is impossible to predict the future, and difficult to speculate about it with accuracy. With this in mind, it is also dangerous to be struck off guard by changes in the economic landscape. The employment rate, as well as the labor force participation rate, have decreased drastically due to the recession in 2007-2009. The economy and the financial world have recovered since the end of that recession, but employment opportunities have not recovered (Brynjolfsson and McAfee 2012, 2-5). Brynjolfsson and McAfee suggest that the lack of recovery in employment could be due to automation (Brynjolfsson and McAfee 2012, 7-9). The historical evidence suggests that general technological innovation does not reduce overall employment. This may be changing as new innovations in automation take shape.

The difference between previous and current automation is in the types of tasks machines are now able to do. Previously, machines could only do routine tasks. Recent innovations, however, have shown that this assumption of routine-only machines is now in peril (Frey and Osborne 2013, 23). In *Jeopardy!*, IBM supercomputer Watson handily defeated the top trivia players in the world (Valerie 2011). This feat proved that non-routine cognitive tasks can be automated. Watson is now servicing patients at a hospital, recognizing patterns, and prescribing treatments (Frey and Osborne 2013, 17).



Expert thinking requires a “schema” (Levy and Murnane 2004, 63). The essence of a schema is building up a mass of long-term knowledge. It is embedded into our brains over years of study. To be an expert in a field, an assortment of knowledge related to the subject must be readily available to the active part of the brain. Also, this assortment of knowledge must be put into practice through experiences directly related to the subject. Medical doctors are an example of this. They do four years of undergraduate school, four years of medical school, and finish with training in residence with the oversight of more experienced doctors. IBM’s Watson is the first computer to be able to come up with answers through a “schema.” It can diagnose patients effectively, as if it had the extensive training of a medical doctor.

Another example is the driverless car developed by Google, which has even surpassed the Mercedes-Benz vehicle mentioned in the introduction (Frey and Osborne 2013, 3). Only ten years ago, the example of driving a car was an “extreme” version of what only humans could do (Levy and Murnane 2004, 13-30). The driverless car is only the beginning of non-routine tasks that computers will be able to do better than humans in the near future.

Other examples of perceptive behavior are *Google Now* and *Apple’s Siri*. Although they are similar to previous search engines, they are tapping into the internet’s resources to customize answers. An example that Frey and Osborne give is *Baxter*, a robot that can be trained to do physical tasks. It is limited in its motions in comparison to a human, but is an advancement in regard to physical automation. There is also development of robots that can do repairs that are unsafe for humans (Frey and Osborne 2013, 18). These robots are breaking grounding in the area of physical perception tasks.

The DARPA Robotics Challenge last year demonstrated these advancements. The winning robot, *Shaft*, especially made advances to do the sort of physical perception tasks that humans do every day in the workplace. “It has driven a small jeep-like car over a short, twisting course, walked over ramps, steps and rubble, negotiated various doorways, cleared debris from its path, cut a hole in a wall with a power tool, connected a fire hose and shut off a series of valves” (*The Economist* 2014).

Based on these observations, Frey and Osborne discuss the future of employment frankly: “We argue that it is largely already technologically possible to automate almost any task, provided that sufficient amounts of

data are gathered for pattern recognition” (Frey and Osborne 2013, 23) As the cost of these machines decrease, so will the incentive for firms to invest in them instead of human capital. If the annual cost of labor is greater than the annual cost to hold and retain these machines for a specific task, then the task will be automated. 47 percent of the US labor market is currently susceptible to automation (Frey and Osborne 2013, 44).

Brynjolfsson and McAfee state that not only is technological progress increasing, but that it will exponentially increase relative to what has happened thus far, and that this will be a structural shift in how labor is arranged. They argue that technological innovation will surpass anything we could ever imagine. They demonstrate that as new ideas come about, more combinations of ideas are possible. As Moore’s law plays out, the hardware that is the foundation of automation will continue to be faster, more affordable, and of better quality. Technological output, they argue, is an exponentially increasing function mathematically (Brynjolfsson and McAfee 2012, 18-21).

Not surprisingly, there are views that differ from those outlined above. Fernald and Jones argue that the future of US economic growth is, and will be, slower than it was for the sixty years after World War II. Since education in the United States has lagged behind other countries in recent years, so will its economy (Fernald and Jones 2014, 5). Poor future growth prospects give an alternative explanation as to why the US has observed poor employment figures since the financial crisis of 2008. They also suggest an alternative view of ideas and technological process. The “fishing out” argument explains that new ideas are more difficult to come about as time moves on. This theory suggests that there is a stopping point to how much innovation can be introduced into the economy (Fernald and Jones 2014, 7). This may only be possible, however, if we go the way of the Amish.

Yet even Fernald and Jones admit that, “In the limit, if capital can replace labor entirely, growth rates could explode, with incomes becoming infinite in finite time” (Fernald and Jones 2014, 8). This statement is mathematical and theoretical of course. It shows that all else equal, the more society automates, the higher the GDP per person will be.

## B. THE END OF WORK THEORY

At the turn of the 20th century, there was significant evidence that the

use of the horse as a means of production was coming to an end. Interestingly, 1901 was the peak year for the number of horses used in production (Brynjolfsson and McAfee 2012, 37). In a similar manner, the labor force participation rate peaked in the year 2000 in the US. At the time, Jeremy Rifkin's "end of work" theory seemed fringe at best. Since that year, the labor force participation rate has declined steadily. A quick glance at the data from the Bureau of Labor Statistics shows this to be the case, as the total percentage of the adult population at work has dropped from 67.3 percent in 2000, to 63 percent today (USBLS 2014).

Recent information demonstrates this too. Between September 2013 and the end of February 2014, the US created 900,000 new jobs (Lazear 2014). A closer inspection shows that the amount of work done by human labor actually decreased. This is because the average work week declined by .3 hours. This may seem minuscule, but it is equivalent to one million lost jobs, for a net decrease of 100,000 equivalent jobs (Lazear 2014). These numbers may add some validity to Rifkin's idea, as well as Brynjolfsson and MacAfee's argument.

In the past, economists have projected a shorter work week in response to the improvements in efficiency and technology. Instead of less work for the same amount of "stuff", humans tend to consume more. As humans demand more, it may be possible to produce those goods through automation. If so, this would either create a shorter work week or a decreasing labor force participation rate.

Historically, there has been a significant decrease in the length of the average work week. In 1850, the average work week was 66 hours, but by 1956, it declined to the typical 40 hour work week (Zeisel 1958, 23-29). This trend has continued, as the average work week has fallen to 34.2 hours, even though the labor force participation rate rose throughout much of the 20th century (Lazear 2014). A large part of the decrease in the length of the work week has been due to labor laws and collective bargaining. The reason this was possible without damaging the economy, however, was technological advances.

## VI. Implications

The pace at which innovation is increasing is higher than it was before, making it more difficult to adjust to the new skills needed for employment. Firms are beginning to automate tasks that they previously could not. Expert thinking and service tasks may be the next to be

automated. The race between the automation of perceptive physical tasks and perceptive mental tasks is important. If expert thinking tasks are automated, it may drive society to be less educated. Service jobs do not require as much education as expert thinking tasks, so the costs of advancing in school would be greater than the reward. This would create negative externalities, such as an uninformed electorate, among other things. If service tasks are automated first, then the demand for higher skills will increase, creating a more educated society.

It seems reasonable that some expert thinking will be automated, but humans will be needed to make the right decision for at least the time being. New innovations will make the decisions more effective and complete. Adjusting away from incorrect past decisions and changing course is still done best by humans. This re-examination of past decisions is called metacognition (Levy and Murnane 2004, 57-59). That does not mean that humans are good at it per se, but that the current supercomputer technology has not yet caught up. Supercomputers like Watson may have schema, but their ability to use metacognition still lags behind humans. Humans will also need to be able to communicate effectively with each other. Building trusting relationships and solving problems with each other seems to be the future of work. As Moore's law plays out, the effectiveness of computers in this area will also increase, making them even better at expert thinking than humans. As for service tasks, the advances in artificial intelligence and robotics may make automation possible in the near future.

Imagine going into a restaurant where the order is taken by a machine, made by a machine, and delivered to you by a robot. Compare this scenario to our current experience. Most people would prefer human interaction over the coldness of a machine-run service. Humans generally prefer human interaction, even if it is not perfect. The machines will need to significantly decrease the cost of production to allow this to happen. If the prices of the fast food, machine-run restaurants decrease significantly more than food served by humans, then customers may make compromises.

In either case, the evidence suggests that automation will reduce the aggregate labor hours needed in the United States in the near future. The way in which this takes form remains to be seen. Past shifts in the demand for labor can help with projecting into the future. Those with the right skills will be gainfully employed and enjoy increased income, and those with the wrong set of skills will be relegated to the unemployed ranks.

Many of the new “jobs” created in the economy will be given to computers, not human workers.

One way in which the aggregate hours could be reduced is through the labor force participation rate continuing to fall. The trend in the U.S. is to have full-time workers put in more hours, while part-time workers become unemployed, or work fewer hours than they desire (Jacobs and Green 1998, 442-444). An alternative would be to decrease the number of hours required for a full-time worker. The work week could be reduced, spreading the required aggregate labor hours to more of the public. If automation proves to reduce the amount of aggregate labor, this might be the correct course of action. Firms naturally try to minimize cost, and so might oppose shortening their full-time employees’ work week.

This also demonstrates that those without capital to invest, as well as those who do not have the education to be gainfully employed in the modern labor market, will share in little of the economic spoils of automation. Unless a different path is charted out, there will be a segment of the population left out of the immense benefits that automation could bring to a society. To be clear, this is speculation about the distribution of benefits due to automation, not about the value of long-run benefits to society as a whole.

Progressives may suggest redistributing wealth as inequality rises. Not only is this approach reactive, but it also could do harm to the framework that has allowed the United States to be the leader in innovation. As was touched on before, the patent system in the USA is essential, because the ability of innovators to profit from their creation in the market is crucial to its sustainability. If the incentives in this system are taken away, then so will the long-term benefits.

In order to give all segments of the population an opportunity to reap those benefits, it is important to renew emphasis on education. As more jobs are automated, the jobs that will be available will be related to complex communication and expert thinking. The demand for these labor qualities must be met with a labor force that is highly educated. The future labor force will need empathetic people skills, even as screens take over the world. The ability to effectively communicate emotional and intellectual messages will be key across industries. The inequality of opportunity is not efficient, and is not desirable for any society. As income inequality naturally grows due to the demand for skilled labor, the US should renew its focus on education (Brynjolfsson and McAfee 2012,

62-63).

The above ideas are an analysis of the labor force in the short to intermediate term. Imagine for a moment, the long-term effects of automation. Moore's law indicates that technology will double in effectiveness in relation to price every eighteen months. If this proves to be true moving forward, and the recent innovations continue to develop, there is not a job that could not be automated. Over time, the price of the capital will decline relative to the price of labor, and therefore capital may replace labor. If this occurs as an economy-wide phenomena, then complete automation will take place. Under the current system, those who own the capital would reap all of the benefits, and those who do not would reap none of it. The main problem with communism currently is the inability to give enough incentive for people to work. If work is not required for the production of the goods we need, then the distribution of those goods could eventually become equal, because the downside of communism would not exist.

Socially, there could be significant downsides. Humans naturally derive joy from being interactive as social beings. Since deepening the most rewarding relationships can be difficult, many may choose interacting with a screen instead. Automation will make this easier. This social expense is a downside that ought to be considered as society moves toward automation. If the derivation of joy is the point of life, it is wise to be wary of how we choose to interact with technology, and each other, as time moves on.

## **VII. Conclusion**

The United States is a global leader in innovation. These innovations have led to rising standards of living for everyone over time. Innovations in routine tasks allow the automation of these tasks. This is largely already happening. Some of the consequences are a shrinking middle class through skill-biased technical change. The next wave of automated innovation is in perceptive tasks, which may automate both low-skill service tasks and higher skilled tasks. As these take shape in the coming years, structural unemployment will increase, and the share of employed Americans will decrease. As this comes about, it is important to boost American educational levels to keep pace with changes in technology. It is important to be wary of the social downsides to automation, as well as to keep in mind that there could be a final destination to automation,

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where machines may replace labor entirely.

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