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THE EMPLOYMENT EFFECTS OF AUTOMATION ADOPTION: PREPARING FOR A FUTURE OF TECHNOLOGICAL UNEMPLOYMENT

CAMERON STEVENS
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Reviewed and approved* by the following:

Russell Chuderewicz
Professor of Economics, Department of Economics
Thesis Supervisor and Honors Adviser

Brian Davis
Professor of Finance, Department of Finance
Faculty Reader

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

This paper contributes to the discussion surrounding the increasing relevance of automation in developed economies and the potential for new technologies to replace human workers, leading to technological unemployment. The intent of this paper is twofold: First, I will defend the thesis that automation is responsible for a significant number of job losses in the manufacturing industry and will contribute to job losses of similar magnitude in the transportation and warehousing industry. Second: I will provide strategies for individuals, businesses, and policy-makers to best-respond to the dynamics of increasingly capable automation technology.

To do this, after discussing a general model for thinking about AI development in chapter one and reviewing a previously conducted study in chapter two, I examine two use-cases of automation, one in the relatively more automated industry of manufacturing and one in an industry that will potentially experience greater levels of automation in the coming decades, the transportation and warehousing industry. From these two case studies, I extract observations about the impact of automation on employment, extrapolate predictions for the potential path of future job losses, and then offer strategies for individuals, businesses, and policy-makers to best respond to future changes. My findings support the theory that automation has and will continue to contribute to the divergence between output and human employment.

TABLE OF CONTENTS

LIST OF FIGURES

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To professors Chuderewicz, Davis, and Jordan, I thank you all for the help that you have given me with the preparation of this thesis. The process of writing this piece has been a difficult but ultimately fulfilling part of my Penn State education. I appreciate the chance to have worked with all of you and your colleagues.

Finally, to any future readers, I am very interested to see how accurate my predictions made here end up becoming. Should I miss the mark entirely, take from my error the lesson that your future is as unknowable to you as your present now is to me. Thank you for reading…

Chapter 1

Introduction

The world economy is now being changed by technologies that once would have been indistinguishable from science fiction. Global networks, allowing instantaneous communication almost anywhere in the world, rely upon machines miles above our heads in the atmosphere, trillions of dollars in commerce are transmitted digitally without a scrap of paper changing hands, and almost every human being in the developed world possesses a pocket-sized device that can access the entirety of mankind's art, music, literary, and film collection (among other more productive functions). This reality, more than a few decades ago, would have been inconceivable to those looking forward. We must be prepared to consider future possibilities that may now seem as unlikely as the present would have seemed to those in the past. It is clear that to find success in the coming years, individuals and businesses must be ready to compete in and take advantage of a rapidly changing, and often-unexpected technological environment.

Automation, the use of machines to increase the productivity of enterprises, is not a new concept. However, recent strides in robotics and artificial intelligence have the potential to greatly expand the effect that automation may have on the type and volume of work that humans perform. Just as the industrial revolution upended the agriculture-based economies of the 19th century, increasingly sophisticated artificial intelligence has the potential to dramatically change the human-based economy of the 21st century. As machines continue to approach and possibly exceed human ability to perform certain tasks, the areas of the economy that demand human skills and labor will shift as they have in the past. While workers will move geographically, retrain, and seek further education to adjust to these changes, the breadth and depth of change that artificial intelligence could bring may introduce competitive pressures that seriously harm employment, increase income inequality, and potentially make obsolete certain skills currently demanded by the labor force. With the thesis that near-future artificial intelligence will have disruptive effects on the demand for human labor, and thus the welfare of human workers, this paper will examine the degree to which employment situations have changed in an already heavily automated industry (manufacturing), and the potential effect of further automation in an industry currently less-accessible to automation integration (transportation and warehousing). This study is intended to better-inform workers, employers, and policy-makers about the near-future impact of artificial intelligence advances on labor markets.

Chapter 2

The Epochs of Automation

The creation of more advanced artificial intelligence is the goal of computer scientists, and the task of implementing automated commercial systems and machines falls upon the world’s talented engineers. I am neither, nor do I expect that my readers will possess the knowledge necessary to plunge into the technical depths of this topic. Thus, it will be useful to utilize a simple heuristic outlined by David Autor to better understand the practical applications and effects of artificial intelligence without diving too deep into the specifics of programming or engineering of these systems (Autor, 2015).

In his essay, Autor outlines a simple progression of how automation (or as he says, computerization) has changed the work that humans do. He says “very roughly, one may characterize the recent phases of computerization as undergoing three successive epochs: simulation, communications, and engagement”. Each epoch of automation coincides with a sequentially progressing level of sophistication in artificial intelligence technology and with increasingly intrusive use-cases into the realm of work previously performed by humans.

Simulation

First, the epoch of simulation addresses the earliest and most basic application of automation, the use of computer code to instruct simple machines to perform a routine task a potentially infinite number of times. While we take it for granted today, the instant and accurate performance of a calculator or an Excel spreadsheet in conducting arithmetic operations, sorting algorithms, and statistical analysis were revolutionary innovations when they were first introduced. We have come a long way from when punch-card technology first increased the efficiency of manufacturing processes by creating replicable mechanical processes, but the significance of this step should not be forgotten.

The powerful advantage of automation in these use-cases is, of course, the reliability and unyielding enthusiasm of the machine's execution of the assigned task. Using automation to simulate routine tasks has brought great efficiency improvements to manufacturing, data management and analysis, and has complemented work done by humans in almost every corner of the economy. Of course, there are still many barriers that the simulation ability is unable to overcome. Foremost is that the machine will be entirely inflexible in its execution of its task. For example, a piece of manufacturing machinery on an assembly line might be able to perfectly create component A of a product while being entirely unaware of and lacking the ability to interact with or create a component B. As I usually tell older family members when assisting with tech support, "[most] computers only do what you tell them to do". Likewise, a traditional machine is unable to attempt or accomplish a task that it has not been explicitly coded to perform. This lack of cognition and environmental awareness is what now sets humans apart from machines. It is precisely this gap that computer scientists are now seeking to bridge.

Communication

With early advances in local networking in the 1980s, and with the commercial adoption of the internet in the 1990s, humans and machines gained the ability to be more communicative and aware of the world outside of their immediate area of work. As we who have lived through the development of this capability can attest, the networking of individuals and machines has profoundly changed the way we work and live. Entirely new industries, from search engines to e-commerce, have sprung up in a matter of decades because of these advances.

The success of these new internet-reliant industries represents another increase in the ability for machines to encroach upon previously human-centric tasks. When machines were restricted to purely simulation-based activities, one might have been able to argue that knowledge-based workers, such as salespeople, librarians, and legal clerks (to name a few) were safe from competition from machines. However, by connecting machines to each other and to petabytes of data and text available online and in company databases, machines have become capable of adequately reproducing through processing power and clever coding what would have taken a human professional years of training or research to accomplish. For example, medication management systems, such as those marketed by the company Dr. First, are able to recommend medications based upon patient history and potential side effects, automatically generate prescriptions, and directly communicate this information to pharmacies (Dr. First, 2017). This innovation is likely quite complementary to the work of physicians, allowing doctors and nurses to spend more time performing subjective and human-centered tasks like caring for patients. However, it is a clear indication that, by connecting machines to communication networks a clear step forward in capability toward human-level performance can be observed.

Engagement

As connected machines become cheaper, and thus more common in everyday life, the networks of connected sensors from which additional data can be harvested grows as well. Today, the concept of “Big Data”, in which information gleaned from user habits, GPS movements, and a myriad of other data inputs is used to create evermore personalized and optimized analysis and experiences. Even though the machines we are using today are still, at their core, simply operating by simulating mathematical operations, the combination of connectivity with other machines, steadily increasing processing power, and with increasingly diverse and accurate data inputs allows machines to “engage” with users and environments and to in some ways “learn” how to perform tasks more optimally.

To illustrate how complex simulation activities can eventually transform into human-level performance in a task, consider a program written by Jonathan Mullen and Joshua Southerland that was designed to learn independently how to play a simple game, Super Mario Brothers. (Mullen & Southerland, 2009). They demonstrated that a computer program, beginning with no concept of the game’s controls or objectives, could train itself to play the game at a level of skill exceeding an experienced human player using a tool known as “genetic algorithms”. The program began the first of its play iterations randomly interacting with the world. After each iteration, the program would receive a score representing the effectiveness of its actions (how far it got in a level). By undergoing an evolutionary process (not unlike the process that formed our own neurological capacity), in which successful actions were passed on to subsequent generations and random “mutations” were included, the program would “learn” the optimal way to play the game. This process, used to “teach” a computer program how to play a simple game, is similar to the methods used to create the programs that have beaten masterful players of more complex games like Chess in 1996 and Go in 2016. Referring to the game of Go, an ancient Chinese game of strategy in which black and white stones are sequentially placed by players to slowly surround board territory, David Lai wrote in 2004:

> The importance and potential of the stones in the game are beyond imagination, resembling the *boundless creativity of human individuals*. Even a super computer today cannot map out their alternatives. Of note here is that in 1997, the IBM super computer Deep Blue finally defeated the chess grand master Garry Kasparov. Yet at the celebration ceremony, the designers of Deep Blue also admitted that they could not write a program to beat even a mediocre Go player, *not any time soon* (Lai, 2004).

It is truly amazing that a machine has now managed to outperform a human in a game thought to represent the “boundless creativity” of a master. When considering the feasibility of further advances in the capabilities of automation it is important to remember that, in the case of the game of Go, “not any time soon” can be as short as just over one decade. These advances have come rapidly and will almost certainly bring dramatic changes to the role of humans in performing tasks necessary to economic operation.

Chapter 3

An Overview of At-Risk Areas

Now that we have outlined the expanded capabilities of automation, how could these capabilities be utilized in the economy of the future? A report by McKinsey and Company has identified areas and activities of the economy that are most and least likely to be affected by present-day technological capabilities (Chui, Manyika, and Miremadi, 2016). Before diving into the findings of the report, it is important to note one key takeaway. The authors of the report write that, "While automation will eliminate very few occupations entirely in the next decade, it will affect portions of almost all jobs to a greater or lesser degree, depending on the type of work they entail".

To compile the report, analysts at McKinsey&Company studied more than 2,000 work activities performed within 800 occupations. The findings of the report discuss the probable degree to which types of work will be automated, not the probability that the entirety of human contributions to the work will be eliminated. Findings from the report communicate the technological feasibility and cost effectiveness of a machine providing an equal or better performance of an activity compared to a human. This information, combined with data concerning the percentage of total time in the economy spent performing such activities, allowed the authors to make macroeconomic conclusions about the potential impact of automation on each industry studied.

Unsurprisingly, predictable physical labor, in which environments and manipulated objects are consistent, was found to be the area that is most ripe for automation. The study found that, in the United States, about one-fifth of the time spent by workers is used to perform routine physical tasks in predictable work environments. By adapting currently available technology, it is estimated that 78% of predictable physical activities could be automated, compared to 25% of unpredictable physical activities.

These findings have profound implications for the industries that most intensively demand this type of activity in day-to-day work. While manufacturing has historically seen the most extensive use of automation due to the cost effectiveness of placing stationary machines on assembly lines, the report estimates that a different industry, accommodations and food services has a higher technical feasibility of automation. Compared to 59% of manufacturing activities, McKinsey estimates that 73% of activities performed by those in the accommodations and food services industry could potentially be automated. The main barriers to automation in this sector of the economy, however, are cost considerations. Given that, in the United States, wages paid to food service workers are often at or below $10 an hour, it is generally unfeasible to replace workers with automated cashier, food preparation, or server systems. Raising minimum wages, or decreases in the cost of converting to automated facilities, however, may change the viability of the business case for automation.

It is important to note, however, that highly automated activities need not be unskilled. The second and third most easily automated tasks described by the report are data processing and data collection activities. Even though these tasks are generally thought of as “knowledge” tasks, in the case of bookkeepers, financial analysts, or accountants, they often are routine in practice. For this reason, there is an observed tendency for these kinds of tasks to be automated to a degree comparable to that observed in routine physical labor. When one also considers the cost savings of replacing semi-skilled routine knowledge workers (who often make well above minimum wage) the business case for automation of these tasks becomes more compelling.

The primary takeaway from this section is that any routine and predictable tasks, regardless of the amount of skill needed to master the task, is going to be more susceptible to automation. As automation conversion costs potentially decrease in the future, it will be the non-routine work that will create the greatest challenge for the expansion of AI involvement in the workplace.

Chapter 4

Automation in the Manufacturing Industry

When considering issues of automation in the workplace, people usually first consider the impact that robotics and artificial intelligence have had on factory manufacturing. This is for good reason, as this industry did provide a fertile environment for some of the first wide-spread adoptions of automation technology. This section will discuss the modern automation technologies that have shaped the manufacturing industry and will examine the effects that these technologies have had on employment and output.

The Development of Modern Technologies in Manufacturing Automation

In industrial settings, the hardware and software that are responsible for automating manufacturing activities are referred to as “control” systems. These control systems can be broken down into “feedback” controls and “sequence” controls. Feedback controls are those that monitor a continuous process and communicate with an output device to maintain the consistency of a measured variable. A controller that is able to “self-correct” without the input of a human user would be known as a “closed-loop” feedback control. For example, a feedback control would likely be used to constantly monitor the temperature of a liquid and automatically make adjustments by communicating with a heater. Sequence controls are those that instruct an output device to carry out a series of steps. These steps can either be linear and fixed or pathed based upon external inputs. For example, a sequence control might be used to instruct an actuator to simply push every other product on a line onto a different conveyor belt, or to even select products to push based upon a visual reading of markings in more advanced systems.

Before the advent of digital control systems, mechanical solutions were sometimes used to accomplish automated control activities. A famous example of this was the centrifugal governor, patented in 1788 by James Watt that could automatically regulate the amount of fuel admitted into a steam engine by opening and closing a valve based upon the speed of a locomotive. While mechanical control systems were ingenious innovations, their reliance on the physical movement of moving parts made it difficult for them to be redesigned to accommodate the demands of various use-cases.

More flexible innovations for industrial use evolved in the 1950s to integrate “numerical control” (NC) systems with punched paper tape and to, shortly after, integrate data processing machines to bring about “computerized numerical control” (CNC) systems. In 1956, development began on a computer system that could autonomously monitor and regulate a wider range of mechanical processes. By 1959 a new technology, known as the digital control system (DCS), allowed a computer to, for the first time, occupy a supervisory role over a range of different mechanical control systems.

While the DCS innovation was useful for monitoring a range of factory processes, the issues of convertibility for different use-cases still remained. The invention of the programmable logic controller (PLC), smaller computational devices that could be programmed to direct and supervise specific processes in a manufacturing environment finally solved this problem. While early PLC’s, such as the famous Modicon (**Mo**dular **Di**gital **Con**troller) PLC, were large and difficult to program, the subsequent increases in processor efficiency and the introduction of simpler programming languages have led to today’s tablet-sized, multi-functional devices

(Hayden, Assante, & Conway, 2014). By combining the direct automation controls of PLC's with the oversight and coordination capabilities of DCS's, the operation of the majority of manufacturing environments can be managed from a single point of control. In the time since, advances in robotics, sensors, resource planning, and of course data processing have continued to augment the productivity of the modern factory.

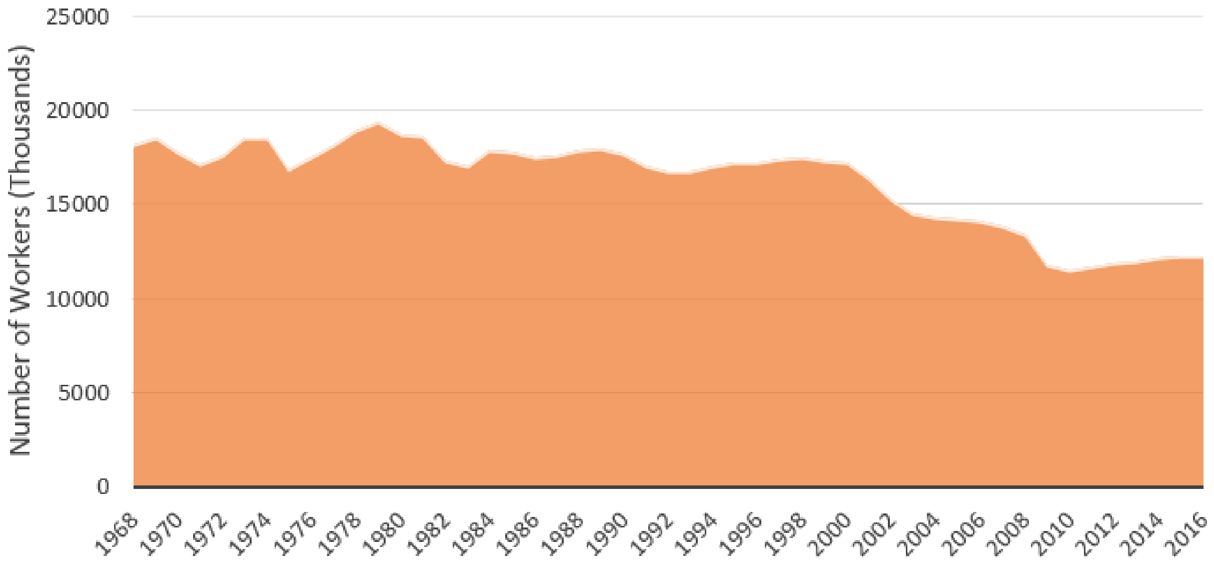
Some companies, especially those that deal in high volumes of standardized products, have even moved toward what is known as "lights out" manufacturing, some of them completely. In such a factory, production processes are automated to such a degree that operations can continue without the normal facilities needed to support human workers like air conditioning, cafeterias, breakrooms, and, as the name suggests, even lighting. The concept itself, of an economy based upon fully autonomous factories, has its roots in science fiction with Philip K. Dick's 1955 short story, "Autofac", but surprisingly there are already multiple facilities that utilize this automation-heavy approach to production. Most famous of these is the Japanese factory of FANUC Robotics, which has used lights-out production runs that have lasted as long as thirty days at a time and has been operating since 2001(Tracy, 2016).

Even though there are cases where lights out manufacturing has been utilized, there are still many barriers that have prevented full adoption of such methods. First, and most difficult to address from a technical standpoint, is the problem of machine reliability. A lights out manufacturing system must be able to consistently perform at a level acceptable to producers, meaning that production problems must be rare, remotely identifiable, and ideally even self-correcting. Production cases with highly diversified products or in extreme temperature or pressure environments are ill-suited for such a hands-off method of production. Artificial intelligence and increasing factory connectedness to the "internet of things" have provided steps toward alleviating these problems, but this problem is still prohibitive in many cases. Next, is the obviously relevant issue of cost. Whether a company is thinking of retrofitting a traditional factory or building a lights out factory from the ground up, the cost of engineering such a specialized system is often prohibitive. As a result, most factories that have gone the way of lights out manufacturing are producers of high-value technological products. Finally, it is important to consider the difficult challenge that the decision to fully automate a factory will have on a company's culture. Replacing workers with machines is unlikely to leave many people happy, and such a dramatic step requires a degree of commitment that is often difficult to garner (Eddy, 2013).

The world has already gotten a taste of lights out manufacturing. If technological barriers to further usage of this method continue to fall, workers might find themselves increasingly competing with more capable machines.

The Impact of Automation on Manufacturing Employment

It is no secret that the American economy has changed greatly over the last few decades. After emerging from World War Two as an industrial and economic superpower, a middle class created by high paying blue collar jobs thrived for the greater part of the second half of the 20th century. Since the turn of the new millennium, however, the story seems to have changed. From 2000 to the present, the number of workers employed in the manufacturing sector has dropped by 5 million, representing a decrease of almost 30%. Viewing the data, we can see that this decrease is representative of a systemic change in the structure of American industry, with levels of manufacturing employment lower than the lowest troughs of late 20th century business cycles (Figure 1).



Source: Bureau of Labor Statistics

Figure 1. The Decline of U.S. Manufacturing Jobs

The policies of the new Trump administration assume that immigration and outsourcing are to blame for blue collar unemployment. After signing the executive order withdrawing the United States from the Trans-Pacific Partnership (TPP), a trade deal that would have lowered trade barriers in South-East Asia in a similar way to how NAFTA opened North American markets, President Trump said, “[It’s a] great thing for the American worker that we just did” (“Trump executive order…”, 2017). Such aversion to trade deals was also represented to a similar degree in the Democratic primary elections with both Bernie Sanders and Hillary Clinton withholding support for the deal.

There is evidence that suggests that this might be an oversimplification of the situation, however. Robert Lawrence, professor of international trade at Harvard's Kennedy School of Government, in an interview with CNN Money in early 2016, points out that U.S. manufacturing employment has seems to have benefitted after past trade deals. Specifically, he notes that, "the nation added 23 million positions in the six years following NAFTA's passage in 1994. Factory employment didn't decline until after 2001" (Luhby, 2016). With this in mind, it is important to attempt to determine the degree to which this decline in manufacturing jobs has originated from multiple sources. Appropriate policy responses will depend upon the results of such determinations.

An important point to note is that manufacturing output in the United States, even accounting for the downturn during the Great Recession, is continuing to grow at a brisk rate (Figure 2.). Hicks and Devaraj, from the Center for Business and Economic Research put it

Figure 2. U.S. Manufacturing Production Index (1919 to 2014)

bluntly by saying “the notion that manufacturing in the United States is in decline is factually incorrect.”(2015).

The critical piece of information that can reconcile declining employment with increased production is worker productivity. Put another way, advances in technology have allowed for production to move forward in a way that is noticeably less labor-intensive. This phenomenon can be illustrated by considering the average product of labor (APL, the value of goods divided by the number of workers required to product those goods) in American industries. From 1998 to 2012, the national average increase of APL was 90%. For some industries that rapidly adopted information systems and robotics, such as computer and electronics products, and motor vehicles, bodies, trailers, and parts, the increase in APL was as high as 829% and 121% respectively. Hicks and Devaraj further expand upon their illustration of this transition by isolating the effect of worker productivity on manufacturing employment levels. Their calculations suggest that, “had we kept 2000-levels of productivity and applied them to 2010-levels of production, we would have required 20.9 million workers. Instead, we employed only 12.1 million.” (2015). [Section derived from (Stevens, 2017)]

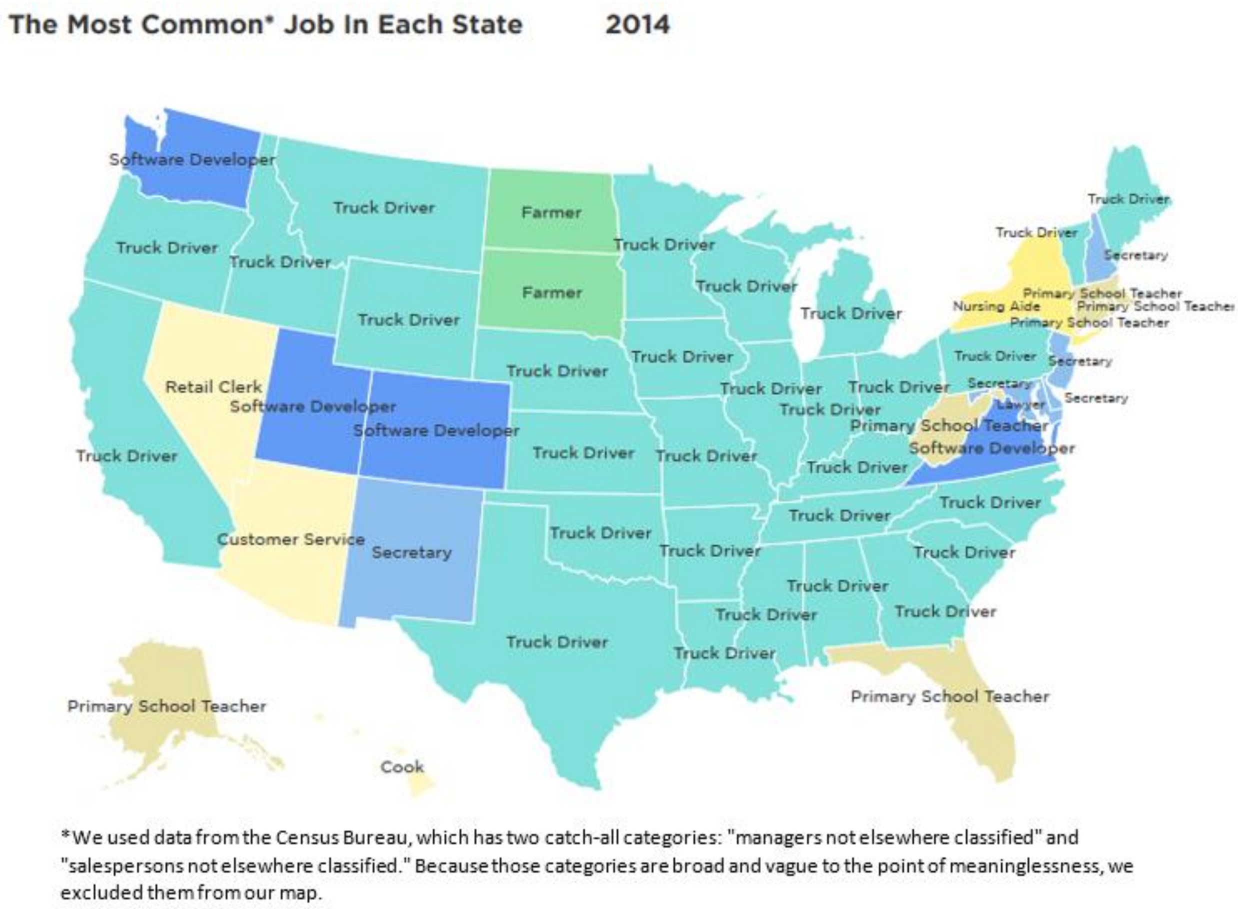
The adoption of robotics and automation technologies in the manufacturing industry has the potential to dramatically change competitive features of that industry in the decades to come. If trends continue, these technologies will continue to rapidly become cheaper and more effective, allowing for continued replacement of human workers with machines. In a 2015 report, BCG, a management consulting firm, estimated that “The prices of hardware and enabling software are projected to drop by more than 20 percent over the next decade. At the same time, the performance of robotics systems will improve by around 5 percent each year.” According to their research, these changes will pass a “takeoff” point for many industries that would make it cost effective to more extensively integrate automated systems. If this is the case, BCG predicts that, “The share of tasks that are performed by robots will rise from a global average of around 10 percent across all manufacturing industries today to around 25 percent by 2025.” This, of course, will drastically change the dynamics of labor markets, and the manufacturing industry. I will discuss these features, and strategies for workers and business to address these changes, further in the last section of this piece.

Chapter 5

Automation in the Transportation and Warehousing Industry

While the automation of the manufacturing industry relied largely on industrial control systems and stationary robotics, recent advances have allowed automation use-cases to extend outside of traditional factory settings. From healthcare to finance, the constantly expanding capabilities of robots and artificial intelligence have enabled the automation of more tasks that traditionally have been performed by humans.

For this second case study, I will specifically focus on the impact that automation has and will have on the transportation and warehousing industry. The industry, which includes "transportation of passengers and cargo, warehousing and storage for goods, scenic and sightseeing transportation, and support activities related to modes of transportation" employed about five million Americans as of January 2017 ("Transportation and Warehousing…", 2017). As seen in the graphic on the next page (Figure 3), an NPR investigation of census bureau data revealed that, as of 2014, in more than half of the states, the most common job was that of a truck driver (Bui, 2015). This demonstrates the important relationship that many Americans have with this industry. It is for this reason that it is necessary to investigate the current and future viability of automation in this industry. Until recently, transportation and warehousing had been isolated from outsourcing and automation, which have largely contributed to job losses in other industries. While the job of a truck driver still can't be outsourced to China, there is the possibility that near future advances in robotics and autonomous vehicle design could allow automated systems to penetrate this industry as well. I will conduct this investigation by reviewing extant technologies, discussing potential "frontier" technologies that might make an impact in the coming decades, and by predicting the effect that these technologies will have on future employment.



The Most Common* Job In Each State 2014

*We used data from the Census Bureau, which has two catch-all categories: "managers not elsewhere classified" and "salespersons not elsewhere classified." Because those categories are broad and vague to the point of meaninglessness, we excluded them from our map.

Figure 3. The Most Common Job in Each State

A Review of Extant Technologies

This review of existing technologies will focus upon two current innovations that are likely to have a large impact on the industry, autonomous road vehicles (AV's) and automated goods handling robotics now utilized in some warehouses. In the present, many of these technologies have been utilized alongside human workers. However, in the future, it is possible that the capabilities of these technologies could improve in such a way that the need for human cooperation is further reduced.

Despite the only recent breakthrough of such technologies into use-cases visible to consumers, the development of autonomous vehicles has taken decades. The foundational research underlying self-driving vehicles goes back as far as the early 80s when both Carnegie Mellon and Bundeswehr University Munich in Germany developed early versions of infrastructure-independent self-driving vehicles (meaning vehicles that can drive themselves on existing roads). Impressively, in July of 1995, CMU's NavLab team even managed to complete a road trip from Pittsburgh to San Diego during which the steering of an otherwise human-operated vehicle was almost entirely controlled by an on-board computer!

In the time since, the development of the technology has been hastened by a number of engineering challenges sponsored by the Defense Advanced Research Projects Agency (DARPA). In 2004 and 2005, the department sponsored two races that challenged engineering teams from universities to design fully autonomous vehicles capable of completing a 150-mile off-road desert course. As a testament to the potentially rapid pace at which such technologies can advance, in 2004, no teams managed to complete the course, but in the 2005 challenge, only eighteen months later, five teams had vehicles that made it to the finish line. The demands on the technology were then escalated in 2007 when a new challenge brought the course into an urban environment, requiring vehicles to obey speed limits and traffic laws. Despite the increased difficulty, six teams still managed to complete the course. These mid-2000 challenges represent the great leaps that AV technologies, specifically sensor systems and computational algorithms, made in the most recent full decade (Anderson et al., 2016).

In the decade since, the DARPA challenges have led to partnerships between universities and car companies, and have even spurred interest from commercial research as well. Most famously, Google's Driverless Car initiative, now rebranded as "Waymo", has successfully driven over two million miles with custom-built autonomous vehicles, the equivalent of over 300 years of human driving experience (Waymo FAQ, 2017). These steps have been mirrored by other companies in the industry as well. As of the summer of 2016, multiple vehicles in Uber's Pittsburgh fleet have been testing fully autonomous vehicles on the hectic streets of the city (with on-board engineers for safety and data-gathering purposes), and Elon Musk, CEO of Tesla motors has claimed that all future Tesla vehicles will be equipped with the hardware necessary to accommodate fully automated software once it becomes available (Chafkin, 2016) (Stewart, 2016).

Attention to the potential offered by AV's can be found even in the stalwart companies of the automotive industry. Numerous new deals have been struck between the world's largest automakers and tech companies that are looking to grab a slice of the growing AV pie. These include partnerships between Audi and Nvidia (a graphics card manufacturer), Microsoft and Volvo, and BMW with Intel and Mobileye (a collision avoidance system manufacturer) to name just a few. The stage has been set for potentially rapid commercial adoption of AV technologies in the coming decades (Stewart, 2017).

While additional advances are still necessary for autonomous vehicles to make their way onto the relatively uncontrolled environments of the open road, free-moving autonomous vehicles have already found commercial utilization in many of the world's warehousing and distribution centers. These, combined with automated warehouse control systems (WCS's) that allow information to quickly travel to workers and hardware, have allowed distribution centers and warehouses to approach the level of automation seen in the manufacturing sector.

Until recently, the job of a worker in a warehouse or distribution center was mainly focused on walking around a facility looking for the materials that an order requested to be shipped. According to Robert Palevich's 2011 book, *The Lean Sustainable Supply,* a typical warehouse worker at the time could be expected to walk for six miles in a typical day looking for materials, representing about 75% of an employee's working time (Fiveash, 2016). Process optimization efforts have mainly focused on decreasing the amount of time that employees need to take in order to find items in a facility, an action referred to in the industry as "picking". The increase in the variety and volume of stock keeping units (SKU's) with the growing popularity of e-commerce has forced facilities to come up with innovative solutions.

The primary solution to this problem in the industry has been the development of facilities built around a "goods-to-person" concept in which a warehouse or distribution center is designed in such a way that employees stand in a small area and pack outgoing shipments with goods that are brought to them. Upon entering a facility, items are stored in a high-volume area that can be accessed by an automated storage and retrieval system (ASRS) such as a carousel or robotics network. Then, when items need to be packed for shipment, the ASRS transports the items to a smaller area where groups of humans or robots sort the items into boxes or other shipping containers (Graves, 2012).

There have been a variety of "goods-to-person" innovations that have been engineered to accommodate the various needs of different industries. While the logistics of a company dealing in high volumes of homogenous products might be best served by a robotics system, a smaller company dealing in products of various shapes and sizes might require a fulfillment system with a more human touch. In either case, however, the efficiency of operations in distributions centers and warehouses has been increased considerably by the integration of automated robotics and data processing. Of course, as with the integration of automated features into manufacturing operations, the cost of implementing new systems and the potential loss of productive time that could result often are prohibitive for companies that might stand to benefit from such innovations.

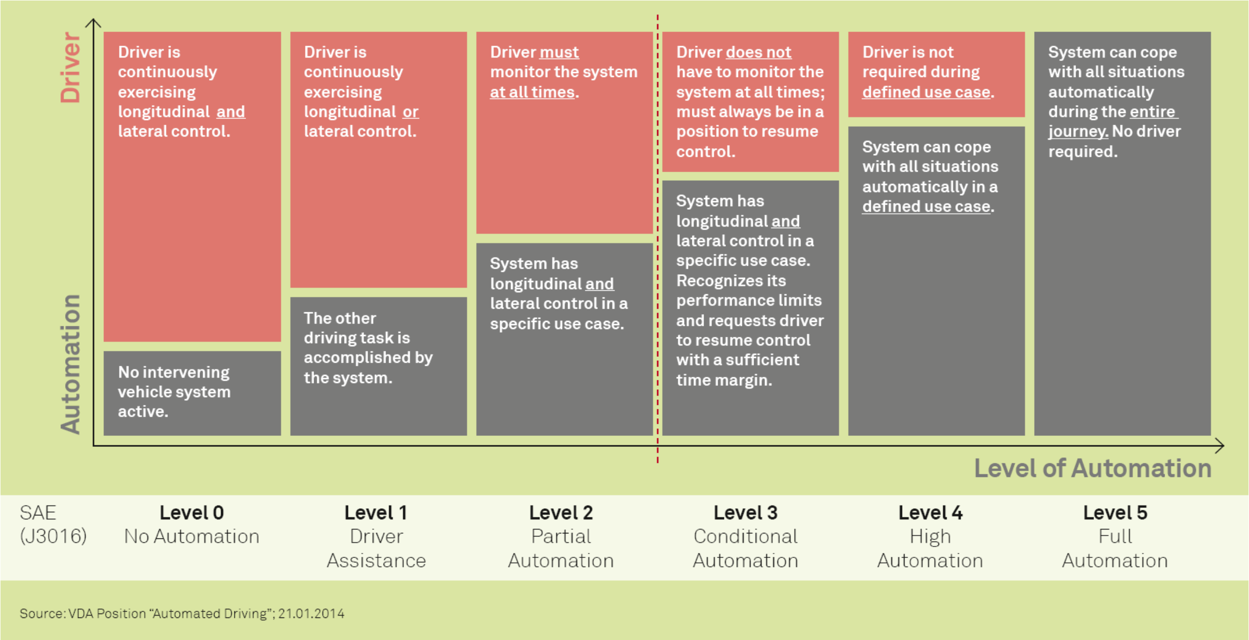
I will refer to two different commercial use-cases to illustrate how automation has been integrated into a variety of logistical facilities: a partially automated system used by Amazon and an almost fully automated system engineered by robotics company Symbotic for the food distribution industry. In many Amazon fulfillment facilities, the company has taken an interesting approach toward integrating robotics into a “goods-to-person” supply chain concept. After acquiring Kiva Systems inc. in 2012, a company known for its cargo-carrying industrial robots, Amazon has become one of the major innovators in the automated logistics space. Kiva’s robots, which take the form of squat, 300 pound boxes on wheels, are capable of retrieving storage containers from a centralized warehouse and transporting them to waiting workers for packaging. The company’s warehouse control system is programmed in such a way that once an order makes its way to a human packer, the worker will find a Kiva robot waiting with the item’s appropriate storage container in front of them (Letzing, 2012). This increase in efficiency has allowed Amazon’s logistical capacity to expand to meet the growing size of its e-commerce business.

Symbotic has taken the concept one step further by designing a fulfillment center that requires no human interaction for the handling of packages. By designing robots that can handle items at all stages of a fulfillment center, including intake, unpacking, storage, picking, and packing, Symbotic has offered a glimpse into the potential future of logistics. At the moment, only retailers like Target with large supply chains can justify paying the price tag of between $40 million and $80 million to buy the necessary equipment. However, those companies that have adopted such a high degree of automation in their logistical operations have seen labor costs reduced by almost 80% and warehouse size efficiency increased by 25% to 40% ([Wall Street Journal], 2016).

The Path of Future Progress

While there are early indications of what the future of automation in the transportation and warehousing industry might look like, there are still a number of hurdles that must be overcome for automated technologies to affect this industry as widely as they have impacted the manufacturing industry. In the case of automated systems in warehousing, the technology needed to implement such systems is present and there are few legal barriers to further adoption, so cost is likely going to be the most prohibitive factor. However, future advances in technology and the benefits of economies of scale will likely reduce these.

More formidable barriers exist on the open road for autonomous vehicles, however. Even though industry tests have verified that fully autonomous vehicles are viable, the technology needed to fully assure the public and policy-makers of the superiority of automated vehicles has still not been attained. Seen below (Figure 4.) is a diagram outlining the U.S. Department of Transportation’s generally accepted rating system for automated vehicles. From left to right, the “levels of automation” increase to represent the growing ability for a vehicle to handle aspects of driving, from full human reliance at level 0 to full independence in level 5 (U.S. Department of Transportation, 2016).



Source: VDA Position "Automated Driving"; 21.01.2014

Figure 4. The Levels of Automobile Automation

At this point, commercially available vehicles have only attained level 2 in which intermediate-level aspects of driving can be handled reliably by the car, but drivers still need to constantly monitor what it is doing. Tesla's current version of its Autopilot system is an example of a level 2 technology, although the company maintains that the hardware will be ready for future upgrades once higher-level software is created. Other companies, including Ford, Mobileye, and Delphi have ambitious goals to skip level 3 technologies entirely and go straight to level 4, citing concerns that drivers overconfident in level 3 technologies might be unprepared to take over in extraordinary circumstances that fall outside of the vehicle's programming. Mobileye and Delphi have predicted that level 4 or 5 vehicles will be available by 2019, while

Ford maintains a more conservative estimate of 2021 (Davies, 2016). In either case, companies are confident that self-driving vehicles are likely going to emerge as a formative dynamic in the industry in the decade to come.

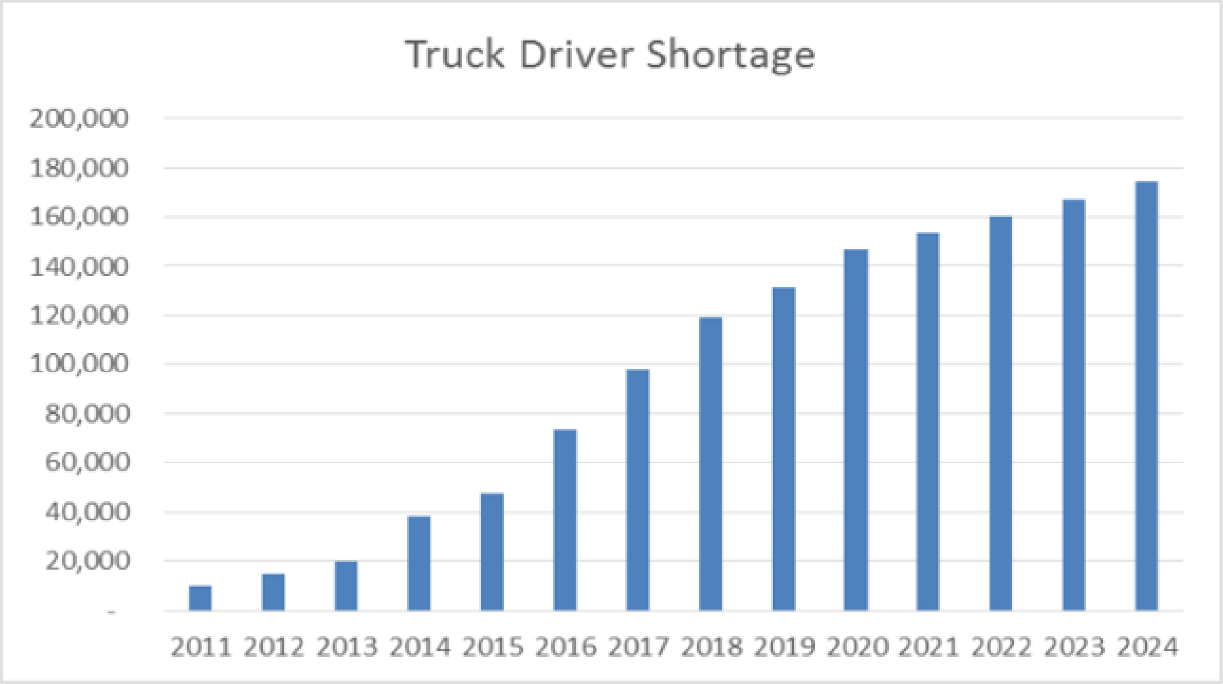
Of course, technologies applied to personal vehicles can also be applied to larger vehicles, including tractor trailers. As stated before, the work of a truck driver is one of the most common jobs in the United States. If adopting autonomous tractor trailers is financially feasible for trucking companies, autonomous vehicle technologies could potentially be as disruptive in that labor market as they are likely going to be in the consumer vehicle market. The next section will evaluate this feasibility and estimate the potential impact that integration of such technologies might have in the coming decades.

Potential Impact on Employment

To begin thinking about how these technologies will influence the industry, it is important to consider the speed with which they could possibly penetrate markets in the coming years. McKinsey&Company, after interviewing multiple industry experts, has theorized a three-stage adoption model for the potentially increasing relevance of automated vehicles. It is important to note that this study considered opportunities for AV's to penetrate both on-road and in-warehouse use-cases. In the company's report, they predict that AV adoption will occur in three primary stages, a developmental phase in which industrial fleets will lead the way, a mixed phase when consumers are beginning to warm up to the idea of AV's, and a final stage when AV's become the primary form of transportation. The predicted time periods for these stages are from the present to 2020, from 2020 to about 2030, and from then onwards. Focusing in on the adoption of such vehicles for commercial use, which will likely contribute the greatest impact to employment, McKinsey predicts, “In the medium term (through 2040), on-highway trucks will likely be the first vehicles to feature the full technology on public roads. Prototypes already exist, and companies are currently developing the software algorithms needed to handle complex driving situations.” (Bertoncello & Wee, 2015)

If these predictions are accurate, the adoption of AV’s could begin to have a large impact on blue-collar employment within the next two decades. In the short term, the integration of automated assistance technologies like lane centering and advanced cruise controls might allow shipping volumes to increase and maintain the stability of human employment in the industry. However, as the capabilities of AV’s improve, trucking companies might find other strategies, such as convoying, in which autonomous vehicles follow a human-directed leader, and even fully autonomous trucks that decrease the need for unskilled human drivers (Clements & Kockelman, 2017).

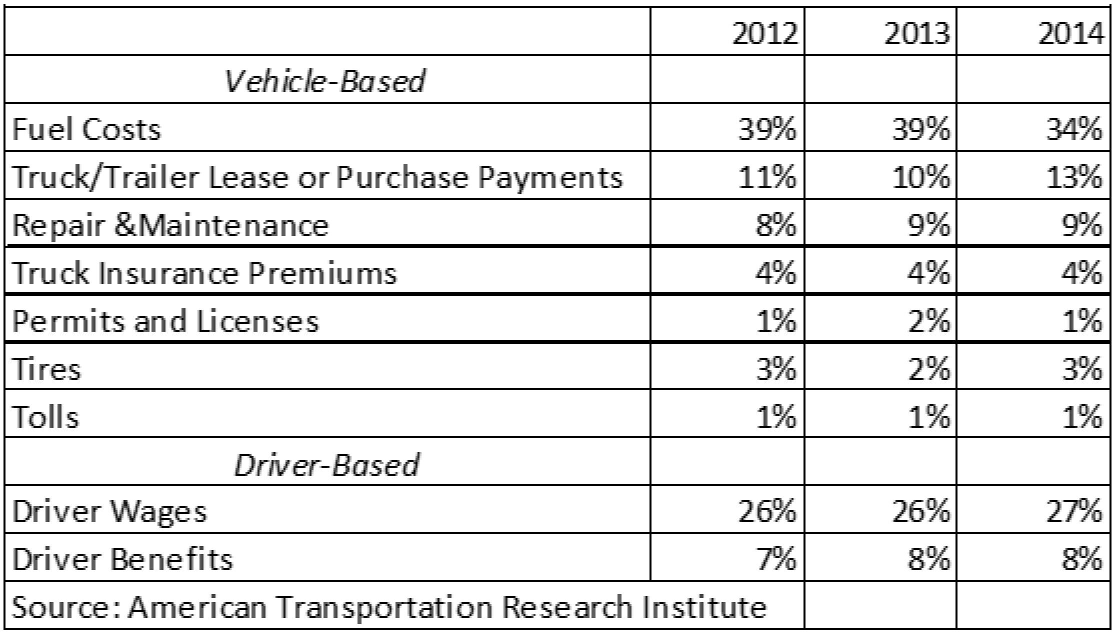
The potential for technological substitution for human labor in this industry is further expanded when we consider that the trucking industry is already having a great deal of trouble fulfilling its need for workers. As of 2014, the industry was experiencing a shortage 38,000 head shortage of drivers. There are a few major phenomena that have contributed to this shortage. First, the industry has experienced a high outgoing turnover in its workforce since the average age of drivers is about 49. The industry has had trouble attracting younger workers to replace those who are retiring due to the work’s long hours and extended time from home. Next, trucking companies, in an effort to maintain professional and respected brands, maintain high hiring standards for applicants. Despite the shortage of workers, in 2012, 88% of fleets said that most applicants simply were not qualified to drive. (Costello, 2015). If this shortage of drivers persists, which the industry seems to believe will be the case (Figure 5.) , it could hasten the adoption of AV's as a way of fulfilling labor needs experienced by trucking companies.



Source: American Trucking Association

Figure 5. Expected Growth of Truck Driver Shortage

The cost structure of most trucking fleets also makes the replacement of human workers attractive as well. A study by the American Transportation Research Institute investigated the proportion of different items in the average trucking company's cost structure. The study found that as much as 36% of the total marginal cost of a trucking company can be directly traced back to wages and benefits paid to workers. This metric, combined with the shortage of workers already experienced by the industry, will put great pressure on companies to invest in AV integration (Torrey & Murray, 2015). It is also worth noting that driverless vehicles could also reduce other major cost items for trucking companies (Figure 6) . If the promise of safer roads and vehicles made by proponents of AV's is delivered, it is likely that truck insurance premiums (currently accounting for 4% of marginal costs) could be reduced. Also, the Eno Center for Transportation Research at the University of Texas has predicted that, at full adoption of AV technology, smoother traffic flows with synchronized accelerating and braking could contribute to a 13 to 25% improvement in fuel efficiency (Fagnant &Kockelman, 2013). These gains would be derived from an automated system's theoretically better ability to drive in a more fuel-conservative manner (e.g. not accelerating while travelling downhill only to break at the bottom).



	2012	2013	2014
Vehicle-Based			
Fuel Costs	39%	39%	34%
Truck/Trailer Lease or Purchase Payments	11%	10%	13%
Repair &Maintenance	8%	9%	9%
Truck Insurance Premiums	4%	4%	4%
Permits and Licenses	1%	2%	1%
Tires	3%	2%	3%
Tolls	1%	1%	1%
Driver-Based			
Driver Wages	26%	26%	27%
Driver Benefits	7%	8%	8%
Source: American Transportation Research Institute			

Figure 6. Share of Marginal Costs for Trucking Companies

However, this data on potential cost savings is only informative when paired with data about the potential cost of implementing a new, fully-automated trucking system. A 2016 study conducted by Roland Berger, a German strategy consulting company, found that the cost of increasing a tractor trailer's "level of automation" ranged from $4,000 to $7,000 per level, meaning that it would likely cost anywhere from $20,000 to $35,000 to fully convert a modern truck to level-5 automation (2016). This estimate is corroborated by the $30,000 price tag of a full automation conversion package that will be offered by Otto, an AV startup recently acquired by Uber (Stewart, 2016). Compared with the average starting salary of a truck driver, however, which in 2015 hovered around $40,260 per year, the potential for cost savings certainly seems likely (Bureau of Labor Statistics, 2016). The conclusion of the Roland Berger study was that, on average, a trucking company could predict a total, per-mile driven cost savings of $1.64 with the adoption of fully-automated tractor trailers.

With these two sides in mind, the technological viability of AV's and the financial feasibility of their integration into commercial operations, I think that it is safe to say that, independent of any serious regulatory hurdles (the effect of which no mortal can reliably predict) AV technology will start being integrated by first movers as soon as it is available. Utilizing McKinsey&Company's three-stage AV adoption model, my timeline of predictions for the employment effects of autonomous trucks on driving jobs is as follows:

Stage 1: Present (2017) to 2020 [Technology Infancy]

At this stage, AV's are still largely relegated to university research and pioneering companies like Google, Tesla, and Uber. It is doubtful that significant enough leaps in the technology will garner the quick favor of companies and policy-makers necessary to begin wide-spread commercial adoption.

There are currently about 3.5M truck drivers, 1.8M of whom are heavy and tractor-trailer truck drivers in the United States (Bureau of Labor Statistics, 2016). I predict no major impact on those jobs in this time period. Employment would likely continue to increase at the current predicted growth rate of 5%.

Stage 2: 2020 to 2030 [First-Mover Adoption and Increasing Reputability]

At some point in this time period, technological sophistication of AV technologies will hit a tipping point at which regulatory and commercial favor is gained. First-movers will prove the viability of the technology and, within a period of three to five years the technology will begin to become a standard in the industry.

The 1.8M heavy truck drivers will likely feel the impact first, as high-volume cargo companies will benefit most from the economies of scaled cost savings offered by AV's. Conversion of human to automated labor will be slow at first, but will become rapid once technologies are proven on the road. Compared to the 30% decline in manufacturing labor observed earlier in this paper, I predict that declines in this industry will be larger and more rapid. The primary reason for this is that the technology and jobs to be automated here are more homogenous than those in manufacturing. The differences between various custom-engineered automation solutions needed for different factories is much greater than the relatively similar AV technologies needed by different trucking companies. In this time period then, I would estimate job losses in this time period to range from 10% in a bearish case on the technology to 40% in a bullish case. These would represent job losses of anywhere from 350 thousand to 1.4M.

Stage 3: 2030 and Onward [Finding a Resting Point]

Finally, at this stage, AV's are expected to be commonplace on the road. Commercially viable use-cases will likely have been implemented at this point. Some younger truckers in the industry might move to more specialized roles that involve maintaining and improving the automated systems or directing platooning caravans. However, it is unlikely that each cab will still need to contain a driver.

The issue at this point in determining employment is in predicting the "resting point" for the industry. How many humans will still be needed when most driving can be done by machines? If the technology is as user-friendly and reliable as some have predicted, it could be reasonable to assume that as much as 70-80% of jobs in the industry might become obsolete. In the scenario in which significant supervision of AV's is still necessary, supervisory roles could offset losses in the driver seats. Such a scenario might only cause a 40-50% decline in

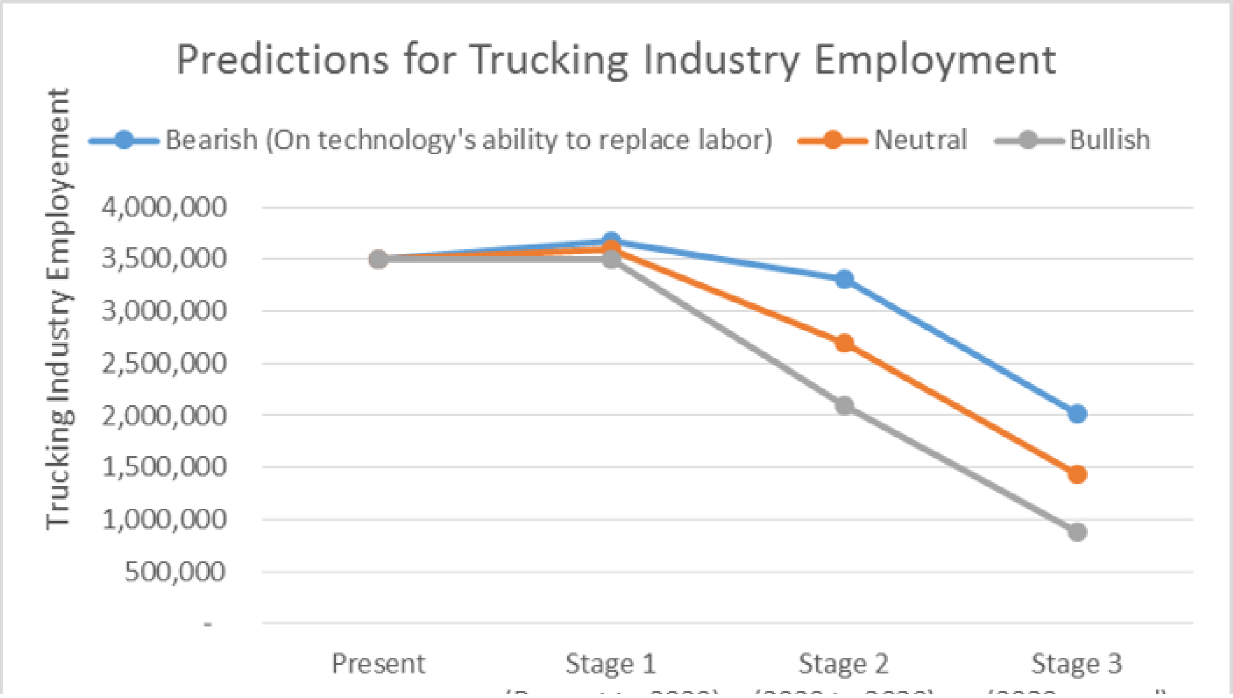


Figure 7. Predictions for Trucking Industry Employment

employment. The chart below summarizes my predictions (Figure 7). I will be very interested to see how closely they correspond with the coming reality.

The potential effect of these job losses is magnified when one considers the multitude of other jobs that rely directly on human truck drivers for businesses. Consider the plight of the owner of a truck stop or diner who notices big-rigs driving past on the open road without a soul on board. No human drivers means no hungry bellies to fill and no money to be spent. Just at the interstate system bypassed many small towns when it was built in the 1950s, autonomous trucks could potentially decrease the demand for services reliant on truck drivers (Collins, 2013)

Strategies for Individuals, Businesses, and Policy-Makers

Despite my attempts here to predict the future, we are all still faced with radical uncertainty about the trends of coming years. Will the promises of artificial intelligence deliver to their full measure and offer a viable replacement for human labor? How quickly will businesses adapt to new technological opportunities? Will new industries rise to replace jobs lost to automation, and how quickly will workers redevelop their skill sets to take advantage of these new opportunities? Do governments have the obligation to intervene with legislation to protect workers, or will they allow free labors to run their course? To answer all of these questions very simply, we do not know. The best we can do is recognize our own uncertainty and do our best to prepare for an unknowable future. After examining these two case studies in manufacturing and transportation and warehousing, I will now attempt to derive lessons and strategies that can be used by individuals, businesses, and policy-makers to make optimal decisions in a potentially tumultuous next few decades.

Individuals

In 2015, the Pew Research Center conducted a poll that asked over 2000 Americans how they believed the economy would change over the next 50 years. 65% of those surveyed said that they believed, “within 50 years robots or computers will “definitely” or “probably” do much of the work currently done by humans”. However, 80% of that very same group also said that they did not expect their own jobs to be radically affected by these changes. Many expressed greater apprehension that their jobs would be taken by other humans willing to accept lower wages, by economic instability, or by employer mismanagement (Smith, 2016).

The general message that can be taken from this divergence between general and personal expectations is that individuals have a tendency to overestimate the security of their own jobs and their irreplaceability in the workplace. As machines and software become increasingly capable of performing tasks at human levels of proficiency, it is dangerous not to be prepared to have to look for work elsewhere. Any further talk of risk-mitigating strategies must be prefaced by a clear awareness of the need to be ready. There is certainly no harm in hoping for the best, but there absolutely is danger in not being prepared for the worst. At the very least, it is a good career development practice to always have an updated resume/cv ready to go, a few key contacts who can be called upon for letters of recommendation, and an emergency fund of three to six months-worth of living expenses in an easily accessible account. These initial preparation measures will prove valuable if you find yourself unexpectedly out of work.

Of course, it would be ideal if you never even found yourself in such a situation in the first place. When considering the susceptibility of your job to replacement by automation, remember the findings of the McKinsey report discussed in the first section of this paper. The jobs that will be easily replaced by machines are those that are routine, sedentary, and less reliant on human interaction. Consider this rule of thumb: if asked, could you, in a few pages, describe in detail what you do to such a degree that another human could perform your task? If you find that clearly defining your work is easy, it is likely that a programmer will be able to design a computer program or robot to do your job. This might be a discouraging revelation, but it is better to realize this and prepare than to ignore it and be caught surprised.

Opportunities to mitigate the risk of unemployment for those who find themselves in such a situation can be found within and outside of your current employer. Consider working with managers and mentors to focus your career development on aspects of your work that involve more creative thinking, interaction with co-workers, and long-term thinking. For example, a bookkeeper currently engaged with logging transactions in a ledger might work with a manager to engineer accounting processes for a new business, program new databases, or advance into a management role for example. The challenge of workers in the future is going to be to find ways to contribute uniquely human qualities to the work that they do.

Even if opportunities to re-brand yourself do not present themselves within your current place of work, there are ways of re-directing your career elsewhere as well. It is likely that the hallmark of this age is going to be consistent education and geographic mobility. Be aware of new technological proficiencies and skillsets that are in demand in your industry and be prepared to put in extra time to accommodate them in your career development. Pursue higher levels of education, take part time classes at community colleges, or even seek out resources online. One of the most in-demand skills at the moment, coding, is a skill that is frequently taught in free online classes and tutorials. The same level of awareness and flexibility is necessary in one’s choice of geographical location. Some industries, especially those that are tied to fixed natural resources like coal mining and forestry, will likely see employment lags in specific areas. Those who find themselves in such locations with few employment prospects will likely be best served by moving.

If the reader takes nothing else away from this paper, take this: Be honest with yourself about the work that you do. If you can reasonably see your work being done by artificial intelligence in the next decade or so, do not despair. Prove the value of your humanity by preparing for the worst, working to contribute more uniquely to your role, and ambitiously pursuing new opportunities to expand your skillset. Humans have come to dominate this world by being more adaptable, more cunning, and more resilient than the challenges that their environment has thrown at them.

Businesses

Of course, on the other side of the economy, businesses will be competing in an environment that is no less cut-throat than the labor market. The promises of automation will continue to offer lucrative opportunities to increase productivity and competitiveness. First movers into the unknown waters of future technologies take a great risk but open themselves to potentially outsized benefits. Businesses that choose not to implement new technological solutions might quickly find themselves falling behind their peers.

Regardless of which industry a company considering implementing automated business processes is operating in, it is important that those planning the adoption are integrating automation strategy with a holistic view of the organizations. Many businesses make the mistake of merely viewing integration as an isolated technology improvement project. Instead, it is necessary for businesses to fully consider all stakeholders and business processes that might be helped and hindered by the adoption of a new, automated business strategy. It might also be useful for a company to consider reaching out to a reputable automated solutions provider that could assist in forming a cohesive strategy (Galeski, 2012).

More specifically, businesses considering implementing an automation-focused strategy should seek to recognize how new technologies will integrate with existing processes. Are there opportunities to fully automate processes from end-to-end? If so, consider prioritizing these projects, as they will likely yield the highest process efficiency improvements. Also, consider the tradeoff between specialized automation solutions for specific tasks and the advantages of having an integrated system that uses standardized code and interfaces across business units. The goal of having relatively standardized technologies for automated processes might be best achieved by creating specialized positions focused on overseeing integration projects. For example, an "automation specialist" might be responsible for organizing coordination between technology implementation teams to ensure that redundancies and inefficiencies are avoided. Finally, it is important that careful metrics before and after projects are tracked. It will be useful to compare actual results post-integration to previously assessed benchmarks. As with any serious undertaking in business, it is necessary to monitor performance in order to improve iterative goal setting and business planning. The path of future projects can be shaped by the lessons learned in current projects (Cauwels, 2014).

Policy-Makers

It is clear that one of the main policy focuses of the current U.S. presidential administration is job creation and maintenance. As I have argued in this paper, no discussion of employment drivers would be complete in the coming decades without a thorough strategy for addressing the millions of Americans who could potentially experience technological unemployment. While it is possible that new industries and jobs will arise to replace those that demand less human labor, it is concerning that very little serious discussion has been had at the national level for addressing this potentially widespread labor displacement. Ultimately, in a system of relatively free markets, the burden to adapt to a changing economic environment is primarily placed on workers themselves. However, policy-makers do play a role in ensuring that ample opportunities for personal advancement are available and affordable and that the alternative to quickly finding a niche in a new economy is not an uncontrolled descent into a cycle of abject poverty. In this section, I will discuss some of the policy suggestions that other countries and world leaders have presented to address technological unemployment.

First, Germany has created one of the most robust vocational training programs in the world. The program is administered by the Federal Institute for Vocational Training and Education and includes an average of two days a week of coursework, coupled with a working apprenticeship in the student's field of choice. By providing a widely available intermediate option between a high school and college education, Germany's work force has taken a critical step toward the skills flexibility needed to weather the strains of technological unemployment (Sirkin, 2013).

Next, in Finland, a pilot program known as "basic income" has attempted to improve the efficiency of the country's unemployment benefits system. The program, which started at the beginning of this year, will provide unemployed Finns a guaranteed sum of €560 (About $600) each month in place of existing programs. This sum will continue to be paid even if the previously unemployed worker finds work lasting a couple of weeks or less. The innovative idea behind this pilot program is that, while the previous system discouraged looking for work by cutting benefits as soon as any income was earned, there are no repercussions for an unemployed worker who wants to earn a personal income through short-term employment opportunities. Similar basic income plans are being tested in other countries across the world as well, including the Netherlands, Italy, and Canada. Plans such as these could alleviate the difficulties of technological unemployment by providing a guaranteed survival stipend for the unemployed while providing incentives for those workers to continue looking for new employment opportunities. It would be prudent for this and future administrations to monitor the effectiveness of these tests (Henley, 2017).

It is important for policy-makers to remember that new technologies will inevitably provide new challenges for the citizens who are counting on them to make the right decisions. The speed and level of innovation inherent in the policy-making process is slow and uninspiring; indeed, our system of government was designed in such a way so as to limit the potentially destructive power of wanton law-making. However, the challenges brought upon by the potential unemployment caused by automation will require unique solutions. Rigorous debate, well-informed research, and a keen eye on the lessons that our peers and predecessors bring will all be necessary to effectively navigate the years to come.

Chapter 6

Conclusion

In this paper, I have attempted to contribute to the discussion surrounding the impact of automation on employment by examining in depth two automation use-cases. The first was in the manufacturing industry where the work environments of factories have been more conducive to automation integration in the past. The second examined the impact of automation on the transportation and warehousing industry with a specific focus given to autonomous vehicles and their potential to disrupt the labor market for truck drivers. I have demonstrated that automation has been a major contributor to job losses in the past two decades, most notably represented by the stark divergence between industrial output and employment.

Evidence has been provided that the future of automation will likely prove to be just as disruptive as its past. The convergence of technical availability of such technologies with the clearly demonstrated business viability of their adoption will continue to offer numerous applications across all industries, not just the ones I have examined here. For this reason, it is important that all participants in the economy (that is to say everybody) approach this future with their eyes open to the possible disruptions caused by advancing levels of automation. It is my hope that my research and strategic advice offered here will make it easier for more actors to make informed and optimal decisions in the decades to come.

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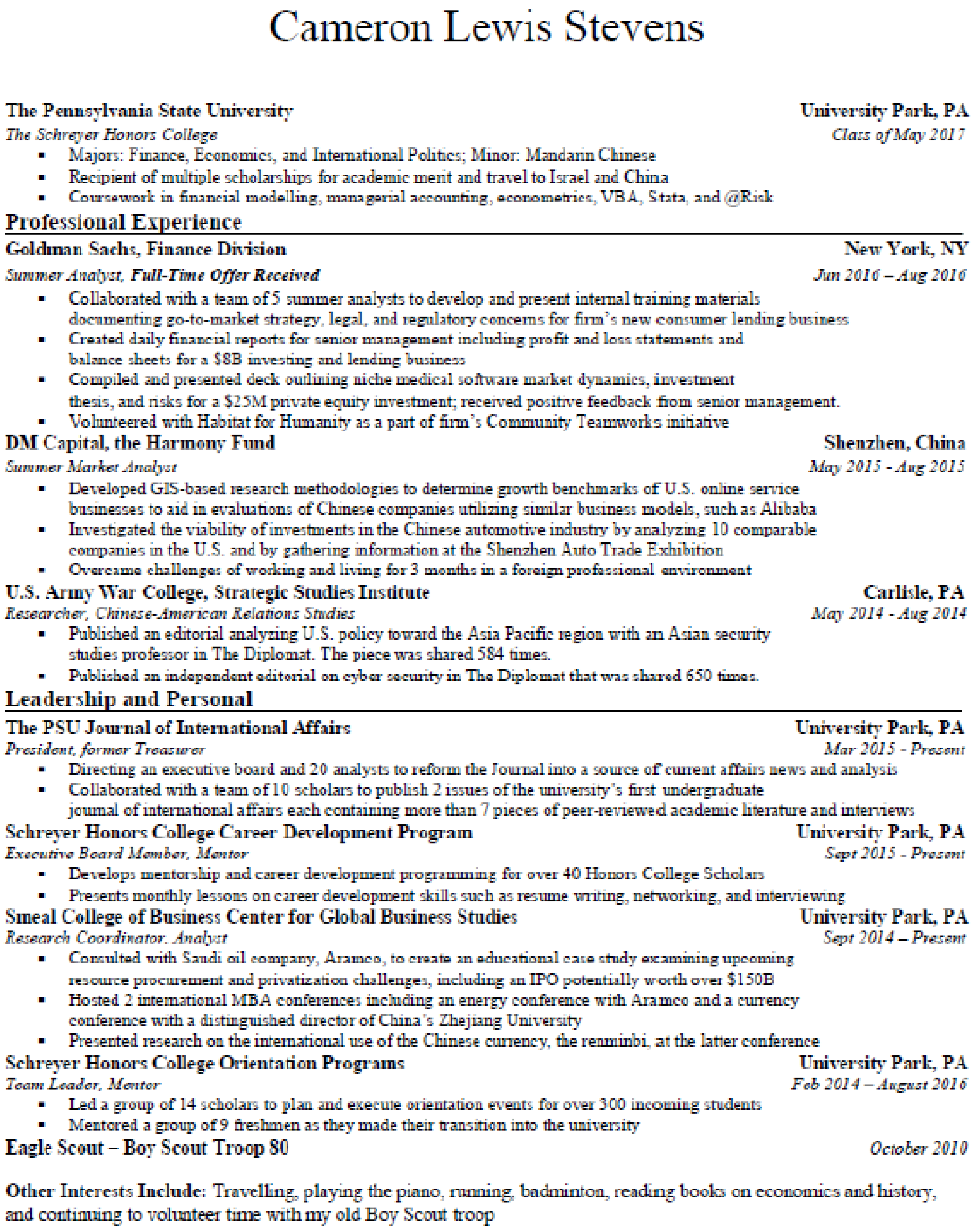
Academic Vita



Cameron Lewis Stevens

The Pennsylvania State University — **University Park, PA**
The Schreyer Honors College — *Class of May 2017*
- Majors: Finance, Economics, and International Politics; Minor: Mandarin Chinese
- Recipient of multiple scholarships for academic merit and travel to Israel and China
- Coursework in financial modelling, managerial accounting, econometrics, VBA, Stata, and @Risk

Professional Experience

Goldman Sachs, Finance Division — **New York, NY**
*Summer Analyst, **Full-Time Offer Received*** — *Jun 2016 – Aug 2016*
- Collaborated with a team of 5 summer analysts to develop and present internal training materials documenting go-to-market strategy, legal, and regulatory concerns for firm's new consumer lending business
- Created daily financial reports for senior management including profit and loss statements and balance sheets for a $8B investing and lending business
- Compiled and presented deck outlining niche medical software market dynamics, investment thesis, and risks for a $25M private equity investment; received positive feedback from senior management.
- Volunteered with Habitat for Humanity as a part of firm's Community Teamworks initiative

DM Capital, the Harmony Fund — **Shenzhen, China**
Summer Market Analyst — *May 2015 - Aug 2015*
- Developed GIS-based research methodologies to determine growth benchmarks of U.S. online service businesses to aid in evaluations of Chinese companies utilizing similar business models, such as Alibaba
- Investigated the viability of investments in the Chinese automotive industry by analyzing 10 comparable companies in the U.S. and by gathering information at the Shenzhen Auto Trade Exhibition
- Overcame challenges of working and living for 3 months in a foreign professional environment

U.S. Army War College, Strategic Studies Institute — **Carlisle, PA**
Researcher, Chinese-American Relations Studies — *May 2014 - Aug 2014*
- Published an editorial analyzing U.S. policy toward the Asia Pacific region with an Asian security studies professor in The Diplomat. The piece was shared 584 times.
- Published an independent editorial on cyber security in The Diplomat that was shared 650 times.

Leadership and Personal

The PSU Journal of International Affairs — **University Park, PA**
President, former Treasurer — *Mar 2015 - Present*
- Directing an executive board and 20 analysts to reform the Journal into a source of current affairs news and analysis
- Collaborated with a team of 10 scholars to publish 2 issues of the university's first undergraduate journal of international affairs each containing more than 7 pieces of peer-reviewed academic literature and interviews

Schreyer Honors College Career Development Program — **University Park, PA**
Executive Board Member, Mentor — *Sept 2015 - Present*
- Develops mentorship and career development programming for over 40 Honors College Scholars
- Presents monthly lessons on career development skills such as resume writing, networking, and interviewing

Smeal College of Business Center for Global Business Studies — **University Park, PA**
Research Coordinator, Analyst — *Sept 2014 – Present*
- Consulted with Saudi oil company, Aramco, to create an educational case study examining upcoming resource procurement and privatization challenges, including an IPO potentially worth over $150B
- Hosted 2 international MBA conferences including an energy conference with Aramco and a currency conference with a distinguished director of China's Zhejiang University
- Presented research on the international use of the Chinese currency, the renminbi, at the latter conference

Schreyer Honors College Orientation Programs — **University Park, PA**
Team Leader, Mentor — *Feb 2014 – August 2016*
- Led a group of 14 scholars to plan and execute orientation events for over 300 incoming students
- Mentored a group of 9 freshmen as they made their transition into the university

Eagle Scout – Boy Scout Troop 80 — *October 2010*

Other Interests Include: Travelling, playing the piano, running, badminton, reading books on economics and history, and continuing to volunteer time with my old Boy Scout troop