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The Political Economy of Automation: Its Effects on Workers Past, Present, and Future

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ABSTRACT

This paper explores the state of the skill premium between skilled and unskilled labor in light of new forms of automation entering the workforce from 2008-2017. I build off the work started by Goldin and Katz in their book, *The Race Between Education and Technology*, answering the question: is demand for skilled labor currently outpacing the supply of skilled labor due to new forms of automation? I start with a historical review of the race between demand and supply of skilled labor, along with a study of policy influences on skilled labor supply. I then examine the literature currently published on automation to see if recent trends show demand for skilled labor increasing or not. I use data from the Bureau of Labor Statistics Current Population Survey to investigate whether current skill premiums have grown, diminished, or remained stagnant compared to the 2000 Census data where Goldin and Katz ended. The trends from this data is then forecasted out to 2020, 2025, 2030, and 2040 to see what current trends would augur for future skill premium levels. Trends points toward the skill premium for skilled labor increasing, contingent on the elasticity of substitution between skilled and unskilled labor. These findings would suggest that the American education system will need to explore supply side policies to keep skill premiums from sky-rocketing and income inequality in check.

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Introduction

Technology and education have interacted with each other for centuries. Ever since the first tool was made to make work easier, humanity has had to spend time learning how to use such tools. As technology has increased in complexity, the demands for intensive education to train workers have also grown. What was yesterday’s wheel is today’s Watson.

Automation is part of the “creative destruction” cycle that pushes production of goods and services into higher levels of efficiency. Old technology is replaced by more innovative, productive creations. Workers using outdated technology will either learn how to use the new technology or become unemployed. This cycle is nothing new. Its historical presence is traceable to computers, cars, cotton gins, and cranes. Yet new technological changes create disruptions. Sometimes these disruptions are minor tremors that cause minimal reshuffling of the workforce. In rare cases, technological changes have the potential to split an economy wide open, causing high levels of unemployment and income inequality as workers are transitioned to new industries. The introduction of artificial intelligence may be one of these rare technologies.

Two Harvard economists, Claudia Goldin and Lawrence Katz, proposed an explanation for why some changes are seismic and others are not. They stated that education is in a constant race with technology (Goldin & Katz, 2008). Sometimes the labor force is intelligent enough that new technology poses little threat to job security since it is simple and easy to master. Other times technology is advanced and complex enough where only a few are able to master its potential. Having the skills to use and create technology is an advantage, as well as the ability to do what technology cannot yet do. This leads to what Goldin and Katz (2008) term the “skill premium”, which is how much more income a “skilled” person makes compared to an “unskilled” person. Skills are defined as the level of education attainment necessary to use new technology which are prone to shift over time as technology increases or decreases the demand for intelligence. The definition also applies to those whose work is still difficult for automation to do since their job may lack routine functions or requires critical thinking. For example, “skilled” labor in the 1940’s was defined as anyone with a high school degree. Now, in 2018, a “skilled” person is defined as someone with a bachelor’s degree. This may be because the ability to critical think and perform tasks that are not routine are of high value. Yet new forms of artificial intelligence and automation may challenge this advantage that humanity holds over technology.

My work will build off the foundation laid by Goldin and Katz (2008). I pick up where they left off, examining the skill premium of skilled and unskilled labor from 2008-2017. These premiums are viewed in the context of automation and its implications on the demand for skilled labor. The results will tell whether education policy needs to focus on increasing the amount of “skilled” labor in the economy to counteract the demand tremors caused by new, complex technology and reduce the potential rise of unemployment and income inequality. It will also permit me to explore whether there is a decrease in demand for skilled labor due to artificial intelligence and automation innovations.

My hypothesis is as follows: demand for skilled labor due to the introduction of new technology will outpace the supply of skilled labor for the years 2008-2017, causing the skill premium for workers with a bachelor’s degree to increase. My second hypothesis is that the skill premium will continue to increase for those with a college degree but at a slower rate for the years 2020-2040. I find that skill premium data from 2008-2017 maintain the narrative that demand for skilled labor is outpacing supply of skilled labor. These findings confirm what

Goldin and Katz (2008) found which is that after the 1970's the skill premium for those with a bachelor's degree has increased in comparison to those with a high school degree. My estimates for future skill premiums show that skilled labor wage premiums will slightly increase, based on the elasticity of substitution exerting a greater influence than the unskilled to skilled labor ratio. This also may be a cause of new technology such as artificial intelligence beginning to compete with skilled labor.

I will explore the historical race between demand for and supply of skilled labor within the United States as well as the literature written on the implications of automation on skilled and unskilled labor to highlight the connection between technology and labor demand shifts. I then provide my theoretical and empirical grounds for my research as well as descriptions of my data sources. My paper will end with an analysis of my empirical results and some concluding remarks on the importance of policy solutions to the skills premium gap that persists.

I. Exploring the Historical Race between Demand and Supply of Skilled Labor in the US:

Automation and its impact on skilled labor is woven throughout American history. From the explosive growth of the Industrial Revolution to the on-going impact of the internet, education has been essential to developing a skilled labor force to capture these technological gains. Exploring the history of automation and education provides context for how public policy responds to these economic tremors. It will also give us a mirror to reflect on when examining the current impact of automation on today's economy and labor. It would be imprudent to look at current trends in the "race" and ignore the history preceding it that can serve as a source of knowledge on what policy solutions are effective and how the two “runners” have interacted with each other when one gets “ahead” of the other.

I will examine in the following sections how the definition and qualifications of skilled labor has changed over time specifically in respect to economic demand. I will also illuminate how societal and economic expectations for education of workers has changed and grown over the past three centuries. I will begin with the Colonial era and end with the early 2000s before exploring automation in the present day and it’s predicted impact on the labor force.

Colonial Era (Colonization to Revolution)

The United States did not formally begin as a nation until 1776. Before then, the eastern seaboard of North America was checkered with European colonies and Native American communities. The establishment of permanent European colonies began as early as 1607, when three ships from England landed in Virginia to establish the colony of Jamestown (Stebbins, 2011). It was the colonies in New England, founded by Puritan settlers from England, that were the educational leaders of the “New World”. There the first universities began to pop up, Harvard being the first in 1636 (Axtell, 1974). New England also was a leader in public schooling, passing the first law mandating communities to provide a public place for education (Axtell, 1974). Surprisingly, it was not economic concerns that catalyzed this education initiative. Religious concerns led to the passage of the “Old Deluder Satan” laws of 1647 in the Massachusetts Bay Colony. Towns of over 50 families had to appoint one person to teach children to read and write while towns of over 100 families had to have a grammar school to prepare children for university (Axtell, 1974). The goal was to have all children be able to read the Bible and understand the religious ceremonies that were central to colonial life. Though religion was a driver for mass education, economic changes in colonial life also facilitated the transition. The initial burden of education lay with the parents of colonial children who would teach their children the Bible and Catechism (Axtell, 1974). But as the economy expanded in colonial America, parents were pulled from the household, leaving a hole for public education to fill (Axtell, 1974). Though public education began to expand in New England, it was still rather shallow in terms of breadth and length of education. Most classes focused on literacy in English and Latin, which was mostly useful for religious purposes (Axtell, 1974). Classrooms were small and were often taught by university students who were in their late teens or early twenties (Axtell, 1974). Most schools were publicly funded, and many communities paid for the education of the children whose parents could not afford to send them to school (Axtell, 1974). Additionally, laws at the time allowed parents to pull their children from school as long as they educated them. Most children in colonial New England took apprenticeships with local skilled workers or took over the family farm (Axtell, 1974). In Boston, most children served as an apprentice for up to seven years or until they turned 21 years old (Axtell, 1974). Length of study would depend on the demand and expected earnings from an occupation. The more important and high-paying an occupation was, the longer an apprentice would study. The demand for apprenticeships may have been due to the reduced demand for university education (clergy-centric) and the prospect of high wages for skilled trade workers in the booming New England economy. This meant that most children in New England would receive a few years of formal education in English and Latin grammar while the rest of their education was either job-specific or family-led. Before the American Revolution skilled labor appeared to be anyone in a trade, such as a blacksmith or lawyer, which at the time did not require a college degree. Therefore, a college degree was not necessary for economic security. Rather, an important apprenticeship was the prize for most New England youth.

There were higher education institutions during the colonial era. For example, Harvard arose out of the need for clergy in New England. Faith was an integral aspect of Puritan life and the demand for educated ministers was very high since the majority of classically trained clergy lay across the Atlantic Ocean. Soon Yale, Dartmouth, William & Mary, and Penn followed in the wake of growing demand for clergy (Noftsinger Jr. & Newbold Jr, 2007). The typical courses consisted of Latin and classes were filled with the sons of well-off members of society. Women and non-white students were not allowed into higher education institutions. The private, religious institutions remained relatively unchanged through most of the colonial era. Technology had not reached a stage where it was a satisfactory substitute for human labor. At this stage technology only helped fuel productivity and expand the economy. It was only after the American Revolution that higher education began to adjust to the new demands of a young republic and a quickly industrializing economy.

Independence and the "Common School Movement"

The American Revolution led to the founding of a new nation that had to quickly learn how to "walk" economically and intellectually. Built on the notion of "equality" for all, America quickly began to examine its education system and the inequality it displayed. More importantly, government leaders were focused on creating an informed citizenry that could uphold a constitutional democracy (Noftsinger Jr. & Newbold Jr, 2007). While religion was the primary catalyst of education reform before Independence, it seems that independence itself became the new driver for education reform. One of the fundamental issues that lawmakers grappled with during this era is the question of access to education. Who should have access and how much education should they have access to?

Upon examination it was clear that education was not universal. Formal education still remained the domain of religious organizations or private schools (Portman, 1978). In New England, the leader of public education, about one-third of children lacked formal education in 1837 (Portman, 1978). The other states can only be assumed to have worse numbers. Many states recognized the need for greater education. But the private nature of education made expansion a bit more challenging. The *Dartmouth v. Woodward* case in 1819 forced states to clarify which universities are public or private since states had limited jurisdiction over private universities (Noftsinger Jr. & Newbold Jr, 2007). This ruling did two things. The first is that private universities spread throughout the newly settled Midwest during the early-to-mid 1800s (Portman, 1978). The second is that states began to establish public universities to enable greater public access to higher education (Portman, 1978). This measure allowed states to increase the supply of skilled labor in order to meet the economic demand. At the time, college education seemed to be an adventure of the elite and challenged the American democratic ideals (Portman, 1978). Additionally, economic leaders desired a better educated workforce in agriculture and industry as new technology arose (Portman, 1978). This led to calls for a "Common School Movement" which started in Massachusetts in 1852 by education reform champion Horace Mann (Portman, 1978). This movement led to many states requiring all residents to undertake a certain number of years of formalized education. All states had some form of compulsory education law by 1918 (Lleras-Muney, 2002). The demand for more skilled labor sets the ground for massive education reforms during the mid-1800s which changed the face of higher education to the present day.

Though calls for greater equality within higher education rose in frequency and decibels during the era following the American Revolution, it should be noted that education during this era was still limited to white children and predominantly men, limiting the skilled labor force pool. Higher education institutions only began becoming co-educational around 1835 (Goldin & Katz, 2011). Slavery in the southern United States made education for black children nigh impossible. In fact, it was in slave owner's interest to keep slaves uneducated. Of those who escaped or were born in the North, education remained unlikely since many communities lacked a school or education remained too expensive that it was an irrational investment. The western expansion of the United States continued to make farming an attractive occupation, dampening the demand for a college education. The Industrial Revolution ultimately changed the societal demand for skilled labor, leading to an increase in the supply of skilled labor as well as changes in how skilled labor was defined. Education began to change from a civic, religious focus to an economic one, in large part due to the heightened levels of industrialization and automation in the American economy. Technology had begun to compete and serve as a substitute for human labor, though it was still in its infancy at this stage and was impacting only portions of the labor force. In fact, technology still led to more employment through economic growth rather than unemployment. The cotton gin allowed cotton farming to expand and sadly, slavery along with it. Technology allowed industry to grow and subsequently forced education policy to respond.

Industrial Revolution and Land Grant Acts

The Industrial Revolution caused dramatic changes in the American economy and education system. O'Rourke, Rahman, and Taylor (2007) found that the Industrial Revolution initially benefitted unskilled labor since the technology used had a low "competence" level needed for operation. As the Industrial Revolution progressed the demand and returns for skilled labor with high levels of "invention knowledge" increased, leading to a rise in demand for higher education to attain this knowledge (O'Rourke, Rahman, & Taylor, 2007). Public leaders responded by passing massive land-mark pieces of education legislation. The Morrill Land Grant Act of 1862 allowed states to set aside land for public higher education (Portman, 1978). Many states seized the opportunity to create nationally-renowned universities such as Ohio State University, University of Wisconsin, University of California-Berkeley, and Texas A&M. These universities were geared towards training young Americans in agriculture and mechanical arts (Portman, 1978). Some schools adopted "tech" in their name since they specialized in developing technical skills that were in increasing demand during the Industrial Revolution (Portman, 1978). The idea of creating land-grant universities stemmed all the way back to the American Revolution. Founding Fathers George Washington and Thomas Jefferson both proposed setting aside federal land for the enhancement of farming techniques and universities (Duemer, 2007).

The establishment of land-grant universities throughout the United States, particularly in the South, Midwest, and West, allowed millions of Americans the opportunity to pursue higher education. The legislation was also historic since it was the first time a nation set aside land for the explicit purpose of promoting higher education (Noftsinger Jr. & Newbold Jr, 2007). The high wages for skilled labor made higher education more attractive to the common citizen.

The demand for skilled labor with a college degree continued to grow, prompting a second Morrill Land Grant Act to be passed in 1890 (Noftsinger Jr. & Newbold Jr, 2007). The Act also established the first historically black universities as well as the training of teachers (Noftsinger Jr. & Newbold Jr, 2007). By 1899, 64 land grant universities had been established, 14 of which were for African-Americans (Portman, 1978). Schools were also becoming co-educational more frequently, with 24 out of the 34 public universities founded after the Civil War being co-educational institutions (Goldin and Katz, 2011). Additionally, 48 percent of private universities founded between 1861 and 1880 were also co-educational (Goldin and Katz, 2011).

Another surge in democratic reform took hold of education in America. Many education leaders and university presidents explored ways to reach the broader population who were unable to physically be on-campus. At the time, most Americans were "educated" by newspapers or libraries (Portman, 1978). Public libraries began to be established around the 1850s though most were established by private philanthropy (Portman, 1978). Lyceums and traveling lectures were also popular though infrequent ways to expand one's knowledge (Portman, 1978). A short-lived but popular solution was correspondence studies, where students were educated by letter (Portman, 1978). This practice was most beneficial for women who were often work or home-bound (Portman, 1978). Subjects ranged from English literature to astronomy (Portman, 1978). The expansion of correspondence studies in the American university system allowed women and the poor to have greater access to higher education. Though the popularity of correspondence study did not last too long, it did give rise to the university extension system which still exists today. The extension system was designed to reach rural communities and those who were not traditional college students (Portman, 1978).

Though skilled labor during this time period were frequently graduates of colleges and universities, the definition cannot be completely narrowed to only those with a college education. Many in-demand occupations did not require a college degree and the lure of wages pulled many American youth out of school by a young age. This would begin to change as the Industrial Revolution entered the twentieth century and the secondary school movement began, particularly with the passage of compulsory school attendance laws and two World Wars. The need for a higher level of base education to handle new technology fueled this growth in education attainment.

Rise of the Secondary School Movement in America and Great Depression

As the Industrial Revolution and automation continued to gain steam and spread into more and more aspects of the economy, the importance of a secondary education began to rise. The economy began to demand higher levels of “Baconian knowledge” or basic necessary knowledge in order to enhance productivity and capture the gains created by new technology (O’Rourke, Rahman, & Taylor, 2007). The median amount of education for an American child increased by about five years from 1890-1940 (Goldin, 1998). The average years of formal schooling for American children was 7.58 years in 1890, while in 1950 it was 12.82 (Goldin, 1998). The high school graduation rate in 1910 was only 10 percent, which makes the graduation rate of 1940, 50 percent, even more impressive (Goldin, 1998). Enrollment rates increased by 500 percent (14 to 70) in 30 years (1910-1940) (Goldin, 1998). That means that by 1940 the average child in America was completing high school. The growth in secondary school completion was a factor of many variables. The economy had begun to create more white-collar and blue-collar jobs that needed workers who had a formal education (Goldin, 1998). High school enrollment and completion rates also increased since new waves of immigrants made child labor less attractive and profitable (Lleras-Muney, 2002). Automation made unskilled labor less necessary, particularly in the agriculture industry since it began to serve as a direct substitute (Lleras-Muney, 2002). Additionally, every state had some form of a compulsory education law by 1918, making it required for children to attend school for a set number of years (Lleras-Muney, 2002). These laws and labor supply changes contributed to the increase in high school completion for American youth, making the exponential increase in enrollment possible.

Interestingly, more high school graduates chose to go into the labor force instead of on to college, particularly when World War I was occurring (Goldin, 1998). This may be due to the fact that the economy was in high need of young, educated workers, making the opportunity cost substantial enough to pull students out of school.

These changes at the secondary level of education caused colleges and universities to change as well. Many West and Midwestern land grant universities like the University of Wisconsin pushed for ambitious extension networks to make university education more accessible to the population (Portman, 1978). Some university presidents saw it as their duty to "serve the common man." (Portman, 1978). There was even a serious discussion about waiving higher education fees for those who missed a high school education as a result of working for their family to avoid poverty (Portman, 1978). Though this idea was not adopted, it shows that those in the tertiary level of education saw a college education as a necessity for the "common man" and the poor, not a luxury of the well-off. Some schools, like the University of Minnesota, traveled around the state putting on educational "demonstrations" and lectures for the local population (Portman, 1978). Additional initiatives to make college education more accessible were the establishment of night classes and the use of the radio (Portman, 1978). The radio became an option to bring the lecture to your living room. Much like the correspondence lessons before, higher education seized the chance to use new technology to spread education. Night classes also made college accessible to the day worker. Night classes tended to serve older students who were seeking ways to increase their professional and vocational training (Portman, 1978). Many of these students were encouraged to attend by their employer who desired an educated workforce (Portman, 1978). The final initiative developed in response to the changes in high school education. The Junior, or two-year colleges, served as an outlet for high school graduates to prepare for a four-year degree or become certified in a vocational degree (Portman, 1978). High schools quickly began to partner with these colleges to offer their high school students an opportunity to take college-level classes (Portman, 1978). This relationship continues today with Advanced Placement (AP), Postsecondary Enrollment Options (PSEO), or College-in-School (CIS) programs.

The Great Depression changed workforce demand for skilled labor and forced education institutions to react accordingly. Colleges experienced declines in student populations (Portman, 1978). Some states offered assistance to workers, such as New York, where unemployed skilled workers were given an opportunity to teach classes to unemployed adults in so-called "Emergency Schools" (Portman, 1978). The University of Minnesota resurrected correspondence studies for high school students who received the equivalent of a one-year college education (Portman, 1978). The federal government took action too, offering American youth an opportunity to earn money and get an advanced education. The Civilian Conservation Corps offered corps members a chance to work and take lessons (Portman, 1978).

Secondary and tertiary levels of education continued to expand education opportunities to women and minority students. In 1934, 64 percent of all four-year institutions were co-educational (Goldin and Katz, 2011). Additionally, women began to graduate from high school at higher rates than their male counterparts (Goldin, 1998). This may be due to discrimination in the workforce or that a young male could make more than a young woman in the early 1900s economy. Minorities were still vastly underrepresented, and segregation continued in colleges and universities across America, particularly in the South.

Technology also began to substitute for labor at a much more pronounced rate, particularly in agriculture where machines could harvest more land at a faster rate than manual labor. This led to a decline in the amount of labor in agriculture and contributed to the labor movement to urban, industrial areas that still needed manual labor.

The definition of skilled labor was becoming more concrete during the early 1900s. Being a skilled laborer meant attaining a high school diploma. Though college education was not considered necessary, especially during the Great Depression, it was becoming more accessible and mainstream. The growth in "Baconian knowledge" due to increased automation in the workforce led to more years of formal education for the average American youth, epitomized by child labor laws and compulsory schooling standards. Unfortunately, the Great Depression led to a lack of demand for skilled labor, making the gains from higher education less visible. But the Second World War and the education revolution behind it quickly rose to meet the new demand for skilled labor.

Post-World War II: the GI Bill, Civil Rights Movement, and Co-education

The Second World War and the education revolution that followed it was a turning point in the definition of skilled labor. After World War II, skilled labor quickly became associated with a college degree of some level, whether it was two-year or more. The number of citizens enrolling in college grew exponentially during the following decades. During the Second World War, colleges and universities were the stations for officers, engineers, and pilots to gain essential training for their tasks (Portman, 1978). After the war, Public Law 346 of the Serviceman's Readjustment Act of 1944, or more commonly known as the "GI Bill", helped bring more than 8 million of these men back to college (Noftsinger Jr. & Newbold Jr., 2007)(Portman, 1978). In 1947, half of all enrolled students at universities were veterans (Portman, 1978). Some causes for the increase in enrollment were 1) a college education became more important for social and economic mobility, 2) the economy was strong enough where help at home was less in demand, 3) higher education was more accessible due to public junior colleges and 4) it was a highly publicized program (Portman, 1978). High school enrollment and graduation rates continued to rise after dipping slightly during World War II, with graduation rates over 60 percent (Goldin, 1998). The dip during World War II was a result of potential students being pulled into the labor force due to the high wages from lack of labor supply due to enlistment (Goldin, 1998).

The other major revolutions occurred in the 1960s, beginning with the Civil Rights Movement. The *Brown v. Board of Education of Topeka, Kansas* decision in 1954 helped break the grip of segregation on higher education institutions (Naftsinger Jr. & Newbold Jr., 2007). The Civil Rights Act of 1964 made it illegal for schools that discriminate by race, gender, sex, or nationality to receive federal funding (Naftsinger Jr. & Newbold Jr., 2007). The 1960s and 1970s were also significant times for women. It was during this time that the most prominent schools, schools such as Harvard, Yale, and the other "Ivy's" become co-educational (Goldin & Katz, 2011). This was possible due to the societal pressures and logic that the best schools should enroll the best candidates, regardless of sex (Goldin & Katz, 2011). Today, most single-sex institutions are religiously-affiliated (Goldin & Katz, 2011). Interestingly, Title IX had little quantitative impact on women enrollment since most schools had already transitioned to being co-educational by 1972 (Goldin & Katz, 2011).

Colleges and universities did not stop experimenting with new technology to expand education during this era. Television became the new, improved radio. Higher education saw television as a way to audibly and visually instruct mass audiences (Portman, 1978). Much like radio, the television lessons did not last long in a formal sense, though many programs today would consider themselves educational. This may be since they were still seen as less effective than formal school lessons. The federal and state government also began to invest heavily in higher education as it became in greater and greater demand (Portman, 1978). The definition of skilled labor had changed following the Second World War. It was now deemed essential to have a college degree to advance economically and socially. The number of college graduates rose by significant percentages in an attempt to catch up to the high level of demand for skilled labor. Automation had continued to advance in a way that made a college degree more attractive. The necessity of math, science, and critical thinking skills became even more important for economic security as the economy began to utilize more technical components. Yet the oversupply of skilled labor dampened wages for skilled workers following the Second World War, despite the growth in demand for skilled labor. But these wages did not stay down for long. In fact, the level of economic inequality may never have been higher than it was from 1970 to our present day.

Modern Era and the Internet

The modern era (1970-present) is very much a continuation of trends that started in the 1940s, 50s, and 60s. The big question for economic and education leaders revolves around the new role of technology. This was identified in the 1950s, where Moffat and Rich (1957) discussed the necessity of retraining programs to equip workers with the technical skills necessary for the workforce. The advent of the Internet has changed the way that knowledge is spread and acquired. Interestingly, automation has even begun to shape the way higher education is delivered and conducted. Many universities have begun to use the Internet as a way to create an easily accessible classroom, much like radio and television before it. In 2002, the University of Phoenix, a popular online university, had over 100,000 students enrolled (Wang, 2009). The expansion of online universities has led to speculation about the creation of Massively Open Online Courses (MOOCs) to replace the traditional colleges and universities (McPherson &

Bacow, 2015). While the speculation may be only hype currently, a 2013 Integrated Postsecondary Education Data survey found that 26 percent of students enrolled in college had taken one online course and 11 percent have received all their education online (McPherson & Bacow, 2015). This is no small amount of the student population and shows that online education is a viable option for many degree-seekers. Even universities that are not solely online use the Internet in their lectures and classes (McPherson & Bacow, 2015). Online education does have some advantages over traditional education formats such as lower fixed costs and larger markets (McPherson & Bacow, 2015). It is also different from television and radio since students have audio and visual cues, along with the ability to pause the lesson and learn at their own pace (McPherson & Bacow, 2015). Many traditional schools have begun to include online courses into their curriculum due to the previously mentioned advantages. The State University of New York (SUNY) now offered over 85 different online certificate and degree programs by 2004 (Moloney & Oakley, 2010). Capella University, an online college, partners with companies like Boeing and Xerox to equip students with the skills these employers desire (Moloney & Oakley, 2010). These universities have been able to expand since the demand for skilled labor has continued to surpass the supply.

A 2004 Council on Competitiveness report emphasized the importance of innovation in American economic competitiveness which includes mastery of artificial intelligence (Naftsinger Jr. & Newbold Jr., 2007). The 2005 Spellings Commission included making higher education more responsive to the new roles of technology as one of their main goals (Naftsinger Jr. & Newbold Jr., 2007). The US National Education Technology Plan of 2010 explicitly recognized the importance of using technology in classrooms along with facilitating life-long learning (Michael & Daniel, 2011). Workplace incorporation of artificial intelligence has led to increased demand for labor with the ability to make critical decisions and who are quick to adapt (Butler-Adam, 2018). Technological literacy has become equally as important as language literacy (Ritz, 2011).

The use of technology such as the internet has attempted to expand the supply of skilled labor during the Modern Era. Students and teachers have both adjusted to use the internet in curriculum and lessons. The explosive expansion of online universities and courses has confirmed this point. Education is not alone in its use of technology. Businesses have stated that technological literacy and worker adaptability are essential for a productive workforce. It is these demands that has forced the education system to adapt.

Automation has led to monumental changes in how we are educated today. We have made schooling mandatory for all children so that every worker has the necessary “Baconian knowledge” for the workforce. We created a comprehensive higher education system that is able to adapt to changes in technology and respond to gaps in the supply of skilled labor. Yet the changing nature of automation today leaves us in an uncertain state about what changes are needed to prepare the future workforce for automated co-workers. What history has shown us is that education and technology follow a “rubber-band” chase sequence where technology advances and education snaps forward to catch up. The incorporation of automation and artificial intelligence in the workforce makes one assume that the demand for skilled labor would increase. Yet there is significant debate among economic scholars about how impactful automation will be on skilled and unskilled labor. Some believe that the new types of innovation can replace even skilled workers, while others believe that only certain occupations may be at risk of significant levels of unemployment. What is agreed upon is that automation is playing a more pronounced role in the workforce today. What is debatable is who it will benefit. By examining these predictions of how automation will impact the labor force it is possible to discern what education solutions are needed to combat the potential growing pains that automation may cause such as income inequality and structural unemployment.

II. Implications and Predictions about automation on the American worker

The debate among economists about how automation will impact the American worker today falls into three different camps: those that believe the new automation will be a substitute for humans, those that believe the new automation will increase employment across all skill levels, and those who believe that it will vary by job and industry. Though all three options are possible, I believe that the third "camp" has the most empirical and theoretical evidence.

Automation is going to destroy jobs

Ever since the Industrial Revolution there has been cyclical warnings of humans entering an age of full automation and full unemployment. While this has not been realized in the present, it is true that what has always been will not always be. New economic data and technical innovations have led some academic and business leaders to predict that human labor is on the verge of becoming irrelevant and uncompetitive. Though there are few, if any cases, to prove that automation leads to widespread, structural unemployment, many academics offer theoretical and empirical models to back their claims. If their predictions hold true, the current state of education will need drastic overhaul to prepare for such demand for skilled labor.

One of the first claims is that the tasks completed by low-skilled labor and high-skilled labor are in jeopardy of being completely automated. Acemoglu and Restrepo (2018b) call into question the concept that high-skill jobs are "immune" to automation. They argue that the expansion of “complex” task automation puts capital in competition with high-skilled labor (Acemoglu & Restrepo, 2018b). When examining how “displacement” and “productivity” effects impact labor markets in high-skilled sectors and low-skilled sectors, specifically with “ripple” effects that causes high-skilled or low-skilled labor to compete with each other when “displacement” is high, they found a decrease in both factors wages which means greater competition between human labor as unemployment rises (Acemoglu & Restrepo, 2018b). Stiglitz and Korinek (2017) theorized that automation will cut out the demand for low-skilled labor, increasing unemployment as high-skilled labor reaped the benefits of greater productivity (Korinek & Stiglitz, 2017). This concern led them to consider what a “technologically unemployed” world will look like, continuing the discussion of a new industrial revolution being the final state for human labor.

Acemoglu and Restrepo (2018c) also focus on the study of task-based instead of factor augmentation. The paper amends the idea that automation is a labor augmenting result if automation is replacing more tasks done at work (Acemoglu & Restrepo, 2018c). It is argued that this will replace labor, perhaps by making it more efficient. These theories lead them to contend that factor augmentation does not adequately illustrate the effect of capital on labor participation. Task-based approaches account for the greater productivity of capital, the deepening of capital, and on equilibrium wage.

Finally, Acemoglu and Restrepo (2017) studied the impacts of automation on local labor markets by regressing the wages and employment changes to the exposure of automation in local markets. They find that an increase of one robot per thousand workers decreases employment by .18-.34 percent and wages by .25-.5 percent (Acemoglu & Restrepo, 2017). In this case, they looked at one sort of automation, industrial robots, and their impact on labor markets and employment. They contend that these robots cause a "displacement effect" on labor since they are in direct competition (Acemoglu & Restrepo, 2017). Acemoglu and Restrepo (2017) do account for international industry trends to remove any labor movement bias. They found manufacturing to be prime for automation and worker displacement.

Do these results contend that humans will "go the way of horses," as described by Brynjolfsson and McAfee? The answer is more nuanced than a simple yes or no. Both authors cite the historical fact that horses were relatively stable in "labor" until the right technology, in this case cars, came along (Brynjolfsson & McAfee, 2015). Yet the authors believe that humans will not go the way of horses due to our willingness for social interaction (Brynjolfsson & McAfee, 2015). Humans will, in short, not go the way of horses since humans can make the conscientious choice not to.

The main concern with the research stating that automation will replace all jobs is that they remain rather theoretical. Though there is logic in the concern of automation replacing jobs since all innovations are meant to do a task previously done by humans or another piece of capital, the assumptions seem a bit stretched for the present economic reality. There is a significant amount of literature that supports employment gains with more innovation with historical context to contradict claims made by those who are wary of full automation.

Automation will grow jobs

Automation does not automatically foreshadow mass unemployment. In fact, there is a significant amount of literature contending that automation will increase net employment for all skill levels. This is usually supported by historical evidence, analysis of industry demand, and the ability of some occupations to be "automation immune" in that they are unlikely to be automated any time soon. If this outcome were to hold true, the state of education would focus on getting more skilled labor into the workforce though the adjustments would not have to be as massive as the ones needed in the first, “doomsday” scenario.

Some optimism comes from a broad analysis of industries and occupations that are high-risk for automation. Some researchers have looked at the difference in job tasks across occupation and industry (Arntz, Gregory, & Zierahn, 2017). This is done since there are large amounts of heterogeneity in the workplace when it comes to tasks that are automatable and those that are not. Some conclusions show that by allowing for these differences in job responsibilities the risk of complete job automation falls to 9% (Arntz, Gregory, & Zierahn, 2017). This stems from looking at the job level tasks instead of occupation level. This leads to the assertion that jobs will be safe and complemented by technology, though a few jobs, around 10% are at high-risk of automation substitution (Arntz, Gregory, & Zierahn, 2017).

Other causes for hope are that some jobs are “immune” whether they are high-skill or low-skill. The idea of immunity is supported by historical data trends. Autor and Dorn (2009) investigated why there was such a sizeable growth in low-skill and high-skill jobs in the 1990’s. They found that low-skill employment and wages rose due to an increase in demand for low-skill service jobs, particularly those where emotional skills are beneficial such as caretaking for the elderly (Autor & Dorn, 2009). This may be due to the difficulties their jobs present for automation since they deal with the surrounding environment and help them be “immune” to automation currently (Autor & Dorn, 2009). Yet Autor and Dorn (2009) did caution that an erosion of “middle-skill” jobs with easily-copied routine tasks is occurring due to automation (Autor & Dorn, 2009). Therefore, if the economy is to grow and for unemployment to stay steady, services and goods must be loosely complementary, meaning the growth in demand and output of one means the growth and output of the other.

Part of the creation of jobs comes from greater efficiency and production. Automation will reduce prices since it makes production more efficient (Bessen, 2018b). This leads to greater demand within an industry which can cause higher amounts of employment if the industry expands. This was historically displayed by the cotton industry in the early and mid-1800s when the cotton gin was introduced. Income elasticity may play a role in industry demand, creating what is believed to be an inverted U-shaped labor demand curve (Bessen, 2018a). This means that if elasticity of a product is greater than 1, jobs will increase (Bessen, 2018a). If it is less than one, jobs will decrease (Bessen, 2018a). AI can either boost job growth if an industries product has generally elastic demand, assuming that the technology does not completely substitute out human labor.

Yet elasticity can vary over time. What about the long-run analysis of automation? Will it ultimately win the race in the end? Berg, Buffie, and Zanna (2018) looked at long-run and short-run variations of different outcomes that have been proposed in other academic papers. They noticed that growth is positive in all cases, such as when robots compete with all labor, low-skill labor, or complementing skilled labor (Berg, Buffie, & Zanna, 2018). These findings tend to support that economic growth will occur and that along with the growth, employment.

Though there is more evidence to support the claim that innovation and automation will lead to further growth in employment, there is reason to not deal in generalizations. There may be a net increase in employment, but that does not mean that all sectors or occupations will see growth. In fact, many sectors will decrease employment due to availability and efficiency of capital. Therefore, most labor analysts, including the studies previously mentioned, tend to claim that there will be a trade-off of jobs. This is the most comprehensive and compelling literature and is what will be looked at next.

Automation will do both

The most likely outcome of automation is that it will both create and replace jobs. What economists are trying to learn more about is exactly which jobs are at risk and which are safe. The literature is still young in this respect, with technology in a constant race against research. Yet there are multiple studies and theories that support the hypothesis that automation will do what it has always done in the past, create greater demand for those who can use it and reduce demand for those in direct competition with its task. These predictions would suggest that higher education would be the vessel to transition those who are structurally unemployed into the high-demand sectors of the economy.

Historically there is reason to believe that automation will act as a destroyer and a creator. Historical cases of automation, such as in the textile industry in the 19^{th} century and agriculture, show that there was a decline in employment in those sectors when new technology was introduced, yet employment still increased overall in the general economy as demand increased for products and new jobs were created (Acemoglu & Restrepo, 2018a). The review of American education history earlier shows that workers adapted through education programs to make themselves employable in the new sectors. This fits with the prediction that automation will hurt and help certain types of labor.

There is a consensus that automation will do two things. The first consequence is a "displacement effect" where automation replaces a task previously done by labor. The second consequence is the "reinstatement effect" which pertains to the growth of the economy due to greater productivity leading to jobs that will be filled by those displaced (Acemoglu & Restrepo, 2018a). This does not mean that automation is a direct substitute for a previous task held by labor, but it is also not going to increase employment automatically. There are concerns about how quickly the transition of labor will occur, specifically with those needing to be retrained. Additionally, business decisions will either accelerate or slow growth in the economy. This is due to the challenge of creating new tasks that involve labor. These factors will all push and pull the labor force and their wage rates, making it difficult to predict exactly how automation will impact employment.

Acemoglu and Restrepo (2016) also considered a different approach to study automation by defining it in two ways. The first is that automation is the use of capital for typical labor tasks, the second is the creation of new tasks in which labor has an advantage over capital. They use this approach to look at automation’s effect on factor prices, factor shares, and employment (Acemoglu & Restrepo, 2016). Their research shows that in this case, all first types of automation decreases wages, employment, and labor share (Acemoglu & Restrepo, 2016). The second type of automation will increase all variables (Acemoglu & Restrepo, 2016). They foresee a balanced growth path where both forms of automation advance equally. The decrease of cost for capital and the productivity gains with labor will incentivize the creation of tasks involving capital and labor, making them stay in relative step (Acemoglu & Restrepo, 2016). This would predict that the market would “self-correct” when capital runs too far ahead of labor.

In conjunction with earlier review, the task/occupation approach may help shed some light into who is at risk and who is not. David Autor (2015) lays out the complexities of the new technological revolution in this context. The answer to the question of whether technology is replacing labor is that “it depends”. Some labor will be substituted by automation and capital while other labor will be complemented, making it more efficient and productive (Autor, 2015). It is subsequently predicted that this new technological wave will create more jobs than destroy (Autor, 2015). The real risk that is identified is that the likelihood of structural unemployment may arise from automation replacing replicable tasks done by certain types of labor, leading to a bifurcated labor force that will consist of high end, managerial jobs, and low skill blue collar work.

This conclusion is supported in other research. Coding certain tasks as “suitable for machine learning” (SML), to understand which occupations will have a sizeable amount of their tasks as “SML” helped further clarify which occupations and jobs are at risk (Brynjolfsson, Mitchell, & Rock, 2018). It is shown that some tasks, like concierges, have high SML scores, while others, like message therapists, are low (Brynjolfsson, Mitchell, & Rock, 2018). The fact remains that very few, if any, jobs can be completely automated. Instead society must prepare for more AI “co-workers” and be trained to use it.

Though the research tends to support this finding, there is still much uncertainty due to a lack of data. Exploring better firm-level data will help economists explore how AI impacts different industries and firms of different sizes. There are currently issues with data access with the best source for macro and micro study of automation, the MGI study, being proprietary and inaccessible (Seamans & Raj, 2018). Having better data on automation at the firm level will help researchers determine how and when AI becomes a complement or a substitute for labor, which types of firms are likely to invest in automation, and how automation impacts firm productivity. Data could also be used to view the impact of automation with a regional lens. Finally, how does educational attainment interact with automation. Are certain degrees likely to lead to automation “immunity” or are all levels of education at risk? This will help further the field in our understanding of automation.

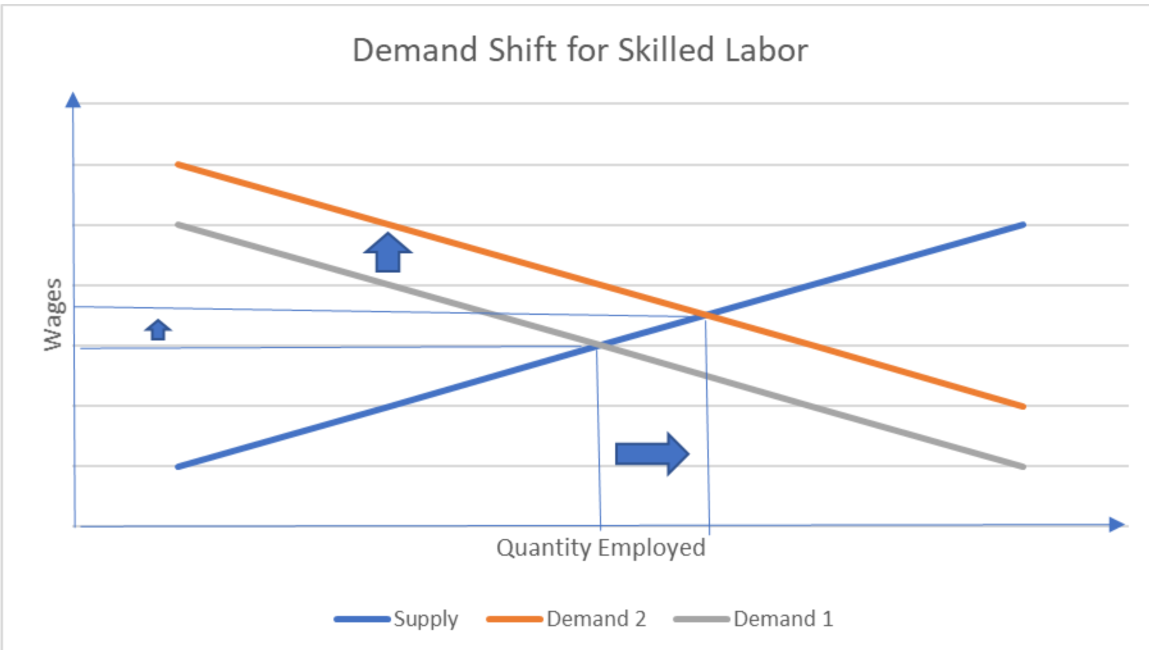
Tying it together: Education’s race against technology

My literature review would be lacking if it failed to mention the inspiration of my research and why I study the history of education and technology in America. Claudia Goldin and Lawrence Katz (2008) proposed that technology and education are in a constant race against each other (Goldin & Katz, 2008). Technology controls the demand for skilled labor while the education system controls the supply of skilled labor (Goldin & Katz, 2008). Technology controls demand in two ways, the first being the demand for labor that has the education to utilize the new technology. The second way is through the extent of what technology can do. There is a demand for workers who do what technology cannot yet master. It is these two ways that skilled labor is demanded and what Goldin and Katz set out to examine. They look at historical data dating back to 1910 to study how education and technology have interacted. Their results show that from 1910-1950, the supply of labor kept pace with the demand for skilled labor (Goldin & Katz, 2008). This trend continued into the 60s and 70s (Goldin & Katz, 2008). It was after 1980 that a significant increase in the skill premium for those with a bachelor's degree occurred (Goldin & Katz, 2008). The data for this is provided in Graph 1. This trend corresponds with national data of income inequality increasing. The argument presented by Goldin and Katz (2008) is that it was after the 1970s that the supply of skilled labor fell behind the demand for skilled labor being set by technology (Goldin & Katz, 2008). These results led them to call for increased enrollment at the tertiary level of education to temper income inequality and match national demand for skilled labor (Goldin & Katz, 2008). My interest stems from my curiosity to understand how the skill premium has changed after their book was published in 2008, especially since technology has become more and more advanced. For example, iPhones were introduced in 2007 and were still in their infant stage. Artificial intelligence was not as widespread then than it is now. Essentially, this decade has seen some significant growth in income inequality and automation, leading speculation that gains from technology are being held by the few laborers with the technical and critical thinking skills to profit from it. It is from this curiosity that I present the theory I will be using as well as empirical methods necessary to build off their research.

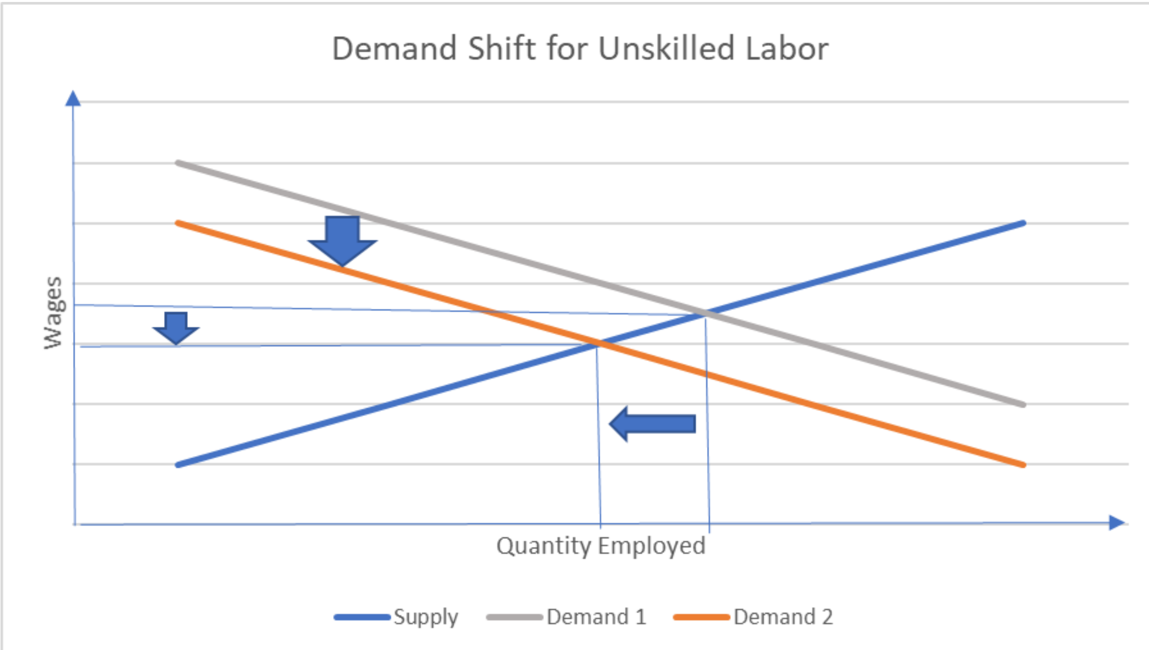
Theory

The theoretical models that I will be using are supply-demand shifts in response to automation. My hypothesis predicts that new technology will create an increase in demand for skilled labor. This is in-line with the research analyzed earlier that saw this new wave of technology as complementary to skilled labor, not as a substitute. As a complement, we would expect it to act as a boost to the demand since an increase in one good leads to an increase in the other. Therefore, supply-demand theory would suggest that new technology will cause the demand curve for skilled labor to shift outwards from the origin.

This means two things. First, the shift of the demand curve away from the origin will mean that wages would increase for skilled labor, assuming a constant supply curve. This theoretical increase in wages may be visible in wage premium data. Automation, in this case, would lead to a higher skill premium for skilled labor if the demand for unskilled labor remained steady. The outward shift of the demand curve would also increase the quantity of skilled labor employed. In the race between technology and education, the supply of the labor force must catch up to demand. As wages increase for skilled labor it is logical to see more people work for those higher wages. As wages increase, so does the quantity of labor employed. It must be noted that the supply curve does not shift in this model. Though there may be empirical evidence that suggests a modest outward shift in the supply curve, it is best for the theoretical models to assume stability so as to limit the number of variables interacting. If the supply curve was to shift, there would have to be calculations between the substitution effect and income effect to predict how wages and quantity employed would be impacted. In this case, we are assuming that the income effect would be larger and therefore shifting the supply curve is unnecessary for theoretical purposes.



The exact opposite applies to unskilled labor. I treat new technology as a substitute for unskilled labor, such as industrial robots for assembly line workers. The increase in demand for a substitute leads to a subsequent decline in demand for the other good. In this case, as the demand for technology increases due to it being more efficient and cheaper, the demand for unskilled labor will shrink. The downward shift in demand will cause wages to fall for unskilled labor. This will also lead to a decrease in the quantity employed. It is from this shift that I would expect the skill premium for unskilled labor to remain the same or decrease. Again, like skilled labor, the supply curve is kept constant and does not shift. This is due to the fact that I am assuming that the income effect would be larger than the substitution effect. Moving the supply curve would become unnecessary for the theoretical model.



How do these two models apply to the skill premium? The skill premium would reflect the demand shifts for each type of labor. If demand for skilled labor increases while demand remains steady or decreases for unskilled labor, then the skill premium for skilled labor will increase due to their higher earnings. This follows my hypothesis that skilled labor will see an increase in demand while unskilled labor will either remain constant or decrease. It is important to note that I am choosing to view skilled and unskilled labor as substitutes as well. If an employer needs a new position filled, they can choose to employ skilled worker or unskilled worker. If the demand for skilled labor increases, then the demand for unskilled labor must fall. To reiterate previously made points, this is because I am assuming that technology is increasing the demand for skilled labor. How the skill premiums are measured is equally as important as the theoretical framework supporting the logic behind my research. My empirical research will complement my theoretical assumptions as a way to explore the state of skill premiums from 2008-2017.

Empirical Analysis

In order to calculate the skill premium I followed the approach that Goldin and Katz (2008) used in their research. They calculated the wage premium as the difference in annual wages of skilled and unskilled labor. They decided to define skilled labor as anyone with a bachelor's degree and I concurred with this definition. Unskilled labor was considered those with only a high school degree. Though the definition could be further explained as anyone without a bachelor's degree, including those that dropped out of high school, I decided to follow suit with Goldin and Katz (2008) to keep consistency in empirical approach. I used the equation below to calculate the skill premium for skilled labor which is denoted as L_S.

$$L_s\ premium = \left(\frac{Median\ annual\ income\ of\ labor\ with\ Bachelors\ degree}{Median\ annual\ income\ of\ labor\ with\ HS\ degree}\right) - 1$$

This equation has the added subtraction of one in order to find the percent difference. If median annual income of labor with a bachelor's degree was $50,000 a year and the median annual income of labor with a high school (HS) degree is $30,000, then the value is 1.667. By subtracting one, I am able to discern the percent premium on a bachelor's degree when compared to a high school degree. This same process was applied to those who have a high school degree and those who have less than a high school degree.

$$HS_{Premium} = \left(\frac{Median\ annual\ income\ of\ labor\ with\ HS\ degree}{Median\ annual\ income\ of\ labor\ with\ LTHS\ degree}\right) - 1$$

This equation allows me to continue the work of Goldin and Katz who also examined the skill premium for those with a high school degree. This helps measure changes over time and simultaneously see if unskilled labor is still distinguished between high school and less than high school (LTHS). If the skill premium of those with a college degree are small and the skill premium for those who have a high school degree are large, then the definition of skilled and unskilled labor may need to change. Such a scenario would suggest that there is little benefit in regards to income by having an advanced degree. Therefore, I analyze both the premium for those with a bachelor's degree and those with a high school degree to see if there are any differences and trends in this last decade.

I also explore the elasticity of substitution between those with a bachelor's degree and those without a bachelor's degree. I use the equation below to examine the relationship between the elasticity of substitution and the skill premium.

$$\frac{Wages_S}{Wages_U} = \frac{\alpha}{1-\alpha} * (\frac{L_U}{L_S})\hat{}(\frac{1}{\sigma})$$

In this equation, wages skilled divided by wages unskilled symbolizes the skill premium for those with a bachelor's degree. L_U stands for all labor within the USA that is without a bachelor's degree. L_S stands for all labor within the USA that holds a bachelor's degree. The greek letter alpha (α) represents the technological change variable which I keep constant. Alpha is valued at $\frac{1}{3}$. With alpha fixed at $\frac{1}{3}$, I assume then that the ratio of $\frac{\alpha}{1-\alpha}$ equals $\frac{1}{2}$. The greek letter sigma (σ), is the elasticity of substitution between skilled labor and unskilled labor.

This method will allow me to calculate the elasticity of substitution between skilled and unskilled labor. My data on the skill premium as well as the labor ratio makes it possible to see if elasticity is increasing, remaining constant, or decreasing over time. If elasticity is greater than one, then skilled labor and unskilled labor are easier to interchange. If elasticity is lower than one, then skilled labor and unskilled labor are much harder to substitute.

My hypothesis would contend that the premium for those with a bachelor's degree is increasing while the premium for those with a high school degree is decreasing. My hypothesis would also predict that the elasticity of substitution is less than one or decreasing. If the elasticity of substitution is decreasing, then under my equation the skill premium for skilled labor would increase, holding all other variables constant. My empirical results will demonstrate that this is, in fact, the case.

Discussion

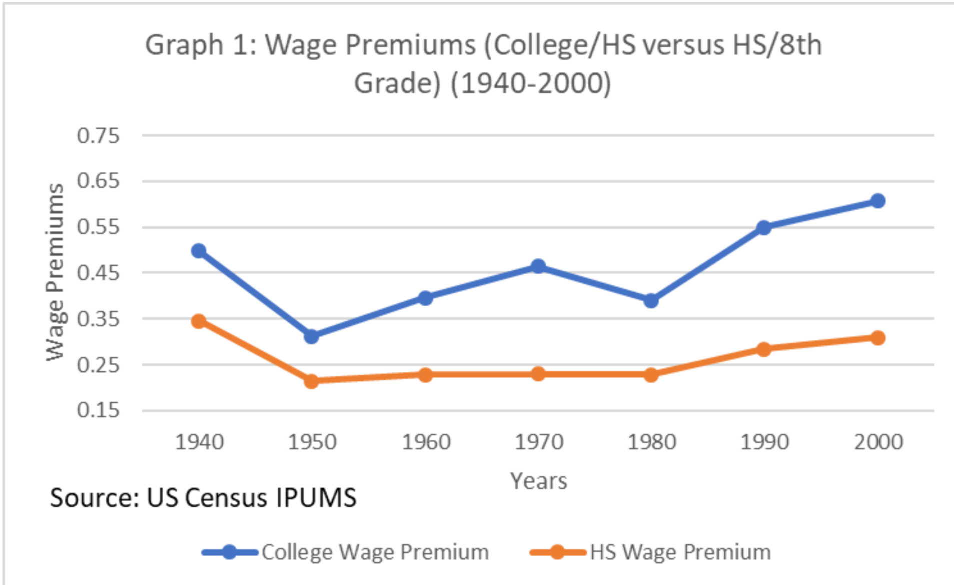
I collected my wage premium data from two sources. The first was from Goldin and Katz, who collected data from the US Census IPUMS databank for the skill (wage) premiums from 1940-2000. My second source was the Bureau of Labor Statistics Current Population Survey, which held median weekly earnings for each education bracket (bachelor's, high school, less than high school). These median weekly earnings were added to reproduce the median annual income that Goldin and Katz (2008) measured from 1940-2000. I followed my premium equation to calculate the skill premium for the years 2008-2017. My graphs show the difference between a bachelor's degree and a high school degree from 1940-2017.

In order to calculate the unskilled labor to skilled labor ratio, I used data from the National Center of Education Statistics to discern what current percentage of the U.S. population held a bachelor's degree and high school degree. This data was inserted into the elasticity of substitution equation. Once my unskilled to skilled labor ratio and skill premiums were calculated (outlined in Appendix Two), I was able to find my elasticity of substitution. I solved for σ by isolating the variable. The process is explained in detail in the data appendix.

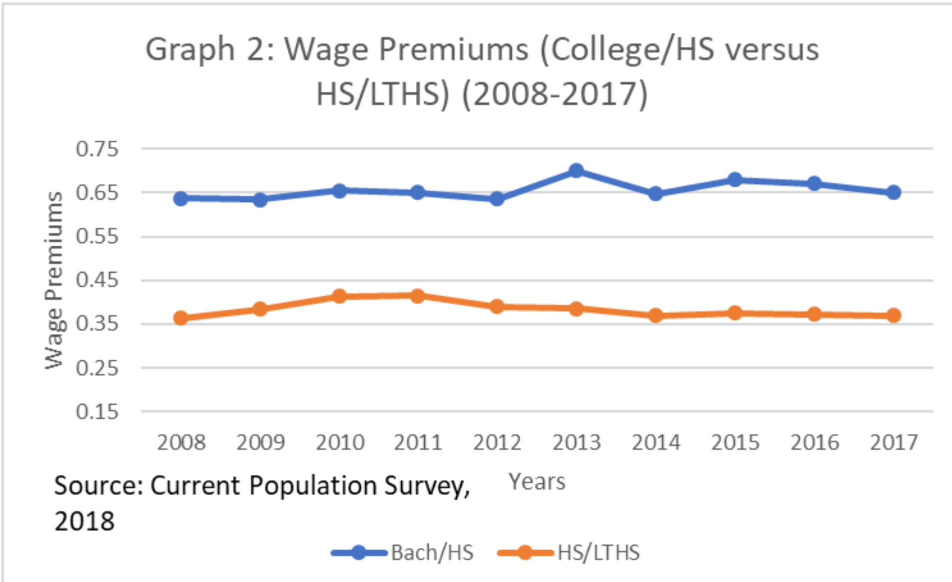
I calculated my projections for the skill premium of those with a bachelor's degree, the unskilled to skilled labor ratio, and elasticity of substitution based off current trends. My skill premium and my unskilled to skilled ratio were projected based off the mean annual change from 2008-2017. The mean annual change simply took the skill premium (percent with bachelor's degree) value in 2017 and subtracted that value with the skill premium (percent with a bachelor's degree) of 2008. This product was then divided by ten to represent the number of years covered in this time span. For 2020, I multiplied the annual change in skill premium (percent with a bachelor's degree) by three (time span elapsed) and added it to the 2017 value. The rest of the process is outlined in the data appendix for each year I projected. I then used these projections to calculate what the elasticity of substitution would be in those select years. Table 1 shows these projections, which are highlighted in yellow. Table 2 shows how the skill premium would change based on different elasticity of substitution values.

Empirical Results

My data confirms my hypothesis that the demand for skilled labor is currently outpacing the supply of skilled labor. On Graph 1 I have displayed the historical data from Goldin and Katz (2008). Their data shows that the skill premium for those with a bachelor's degree rose rapidly after 1980. It rose from .391 in 1980 to .607 in 2000. This is different than their findings which show that in the mid-1900s, the skill premium for those with a bachelor's degree decreased. This may be due to the fact that supply of skilled labor increased compared to the demand. Policies such as the GI bill may have led to the increase in supply of those with a bachelor's degree. Additionally, the value of a high school degree was still high since a significant portion of America did not graduate from high school.



Looking at the data on Graph 2, which represent the skill premium from 2008-2017, it is clear that skill premiums picked up where Goldin and Katz (2008) left off. In 2008, the skill premium for those with a bachelor's degree was .637. This means that the average annual wage for those with a bachelor's degree was 63.7 percent higher than the average annual wage of a worker with only a high school degree. This gap remains relatively stable over this 10-year span. It peaks at about .70 in 2013. The total change from 2000, which had a premium of .607, to 2017, which had a premium of .650, is .043. This is an increase in the skill premium for those with a bachelor's degree. Under the theory put forth by Goldin and Katz (2008), the explanation would either have to be that the supply of skilled labor is decreasing or the demand for skilled labor is increasing. The answer must be that the demand for skilled labor is increasing since the ratio of unskilled to skilled labor is decreasing (Table 1). The growth rate of the percent of the U.S. population with a bachelor's degree has also slowed in previous decades, reinforcing the claim that supply has been falling behind but not backward (Supplementary Table Graph 3). If the ratio was remaining stable or increasing, then the scenario where skilled labor is actually decreasing as a percentage of the workforce would be plausible. However, since the unskilled to skilled labor ratio is falling, I can say that the growth in the skill premium is due to a greater increase in demand.



A thorough examination of Table 1 and Table 2 will unveil some interesting trends for the 2008-2017 time span. First, the wage premium stays fairly constant over time, with minor fluctuations. The unskilled labor to skilled labor ratio continually drops. This is because a greater percentage of the population is holding a bachelor's degree. The elasticity of substitution also falls during the 10 year time span. It starts out very elastic, which means that skilled and unskilled labor are easier to substitute. As years progressed, it became more inelastic which means that the substitutability of skilled and unskilled labor is now much harder. The highlighted sections represent my projections for the three variables for the years 2020, 2025, 2030, and 2040. These projections are simulations of what the wage (skill) premium would look like if it followed current trends. Trends suggest that it would increase, though at a slow rate. The projection of the unskilled to skilled ratio reflects the projected increase in the percentage of the population with a bachelor's degree. 23 years from now, the United States can expect roughly 45 percent of the population to hold a bachelor's degree based off the growth rates from 2008-2017 (see Supplementary Tables Table 3.1). By holding wage premiums and the labor ratio increasing and decreasing, respectively, I can project the elasticity of substitution. My projections show the elasticity of substitution becoming more inelastic as time progresses.

Table 1.			
Years	Wage Premium (Ls/Lu) (Actual)	(Lu/Ls)	Elasticity of Substitution (Actual)
2008	0.637	2.4	3.61
2009	0.635	2.39	3.66
2010	0.654	2.34	3.17
2011	0.651	2.29	3.14
2012	0.635	2.24	3.36
2013	0.7	2.15	2.28
2014	0.647	2.13	2.93
2015	0.68	2.08	2.38
2016	0.671	1.99	2.35
2017	0.651	1.92	2.48
2020*	0.655	1.805836	2.19
2025*	0.662	1.628812	1.74
2030*	0.669	1.472799	1.33
2040*	0.683	1.210433	0.61

In Table 2, I simulate what the wage premium would be if labor ratio projections were held steady and elasticity were inelastic, elastic, unit elastic, or steady based off 2017 levels. I offer four different scenarios, one where unskilled and skilled labor are very substitutable ($\sigma=5$), where they are not easily substitutable ($\sigma=0.8$), unit elastic ($\sigma=1$), and if elasticity remained at 2017 levels ($\sigma=2.48$). In all cases, the wage premium decreases over time. This is mostly due to the fact that the labor ratio decreases. What is interesting is that the more inelastic simulations have the higher wage premiums in 2040. The inelastic simulations also see the greatest amount of change over the 20 year range. For example, an elasticity of .80 would have a wage premium of 1.047 in 2020 and a wage premium of .635 in 2040. Meanwhile, an elasticity of 5 only sees a .05 decrease in wage premiums over this timeframe.

Table 2.				
Years	Wage Premium (σ=2.48)	Wage Premium (σ=5)	Wage Premium (σ=.80)	Wage Premium (σ=1)
2020*	0.635	0.563	1.047	0.903
2025*	0.609	0.551	0.920	0.814
2030*	0.584	0.540	0.811	0.736
2040*	0.540	0.519	0.635	0.605

These results suggest that maintaining the downward trend in unskilled to skilled labor ratio will ultimately decrease the skills premium, holding elasticity at a fixed rate. In 2040, the skill premium for those with a bachelor's degree will vary slightly from where it is today, depending on the elasticity. The only large shocks would occur if the elasticity of substitution became significantly inelastic in a short amount of time. The results suggest that as the wage premium is very sensitive to the changes in elasticity and labor ratio. If the labor ratio is falling faster than the elasticity of substitution is becoming inelastic, then the wage premium will decrease. If elasticity of substitution becomes more inelastic faster than the labor ratio decreases, then the skill premium will increase. Essentially, it is a race between automation and its influence on the importance of skilled labor (elasticity of substitution) versus the supply of skilled labor (skilled versus unskilled ratio), as stated in the theory proposed by Goldin and Katz (2008).

III. Conclusion

The results from this paper reinforce the theory proposed by Goldin and Katz in 2008. The wage premium has continued to rise during the decade since their book was published. The race is currently being won by technology, which is increasing the demand for skilled labor. The demand for skilled labor is increasing the wage premium. Though the supply of skilled labor has been increasing, it has been increasing at a much slower rate than the demand for technology.

Therefore, income inequality is continuing to expand and education policy will soon have to adjust their practices in response to social and economic pressure. This may take the form of increased online education as a way to increase access as many universities have been doing. This solution builds off the long history of university outreach programs, whether it is by correspondence, radio, or television. As mentioned earlier, there is greater hope that the internet will succeed where these other methods failed since it allows people to learn at their own pace and from home. But this solution is only possible if broadband access is everywhere and not available in only certain geographic areas. It will also be important to train labor in critical thinking and other skills which remain difficult to automate. A liberal arts education can provide more well-rounded workers who have the flexibility to move between industries as demand may fluctuate.

Projecting into the future, the skill premium will vary based off how quickly the supply of skilled labor increases in comparison to the elasticity of substitution. If the elasticity of substitution becomes more inelastic faster than the supply of skilled labor increases, then the wage premium will increase. If the opposite is true, then the wage premium will fall.

These findings suggest that skilled labor will not see a significant decrease in wages. Holding a bachelor's degree will still be a wise investment, even with the projected increase in those reaching a bachelor degree educational attainment. New technology is creating a big enough shift in demand where stable skill premium levels would persist. The tremors appear to be relatively minor. But it should be made clear, tremors are and still will occur. Smart policies that boost the supply of skilled labor will be necessary to ensure stable skill premiums and tamed income inequality. More men and women may seek to transition into college to attain bachelor's degrees which means having adequate resources such a facilities and faculty will be essential.

Providing tuition assistance becomes equally imperative as a means to opening up bachelor degree attainment for current financially-constrained workers. The 21st century workforce will require a labor force that is skilled in how to use technology and do what technology still cannot yet do. Preparing for this future now will help the United States manage the larger shocks that may come in the future.

This work can be expanded upon in many different directions. First, exploration of specific industries will allow policy analysts and economists to predict which industries may be hit the hardest by automation. Using the demand elasticity theory of Bessen would be applicable in this situation. This paper could also be altered by changing the definition of skilled labor to those with a bachelor's degree and associate's degree or technical school training. Perhaps a bachelor's degree is not necessary to reap the benefits of technology. Studying the skill premium between those with an associate's degree and high school diploma can indicate whether my current definition is adequate or not.

Technology and education will always be in a race with each other. The last half-century would suggest that technology is outpacing the supply of skilled labor. This new era of automation will certainly cause shocks to the labor force and the economy. It is up to policymakers to prepare the labor force for the shifts in technology. The supply of skilled labor must increase to match demand if gains from technology are to be widely shared, spurring greater innovation within our education systems to provide all an opportunity to enjoy the gains from new technology and limit the growth of income inequality between those of different education levels.

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Data Source Appendix

<u>Appendix One:</u> Calculating Elasticity of Substitution

My simulations involving elasticity of substitution were completed by following these mathematical steps.

Step 1: Bring technological change variable to the wage premium side of the equation

$$(\frac{Wages_S}{Wages_U})/\frac{\alpha}{1-\alpha} = (\frac{\alpha}{1-\alpha} * \left(\frac{L_U}{L_S}\right)^{\frac{1}{\sigma}})/\frac{\alpha}{1-\alpha}$$

This step would then create the following equation:

$$(\frac{Wages_S}{Wages_U})/\frac{\alpha}{1-\alpha} = \left(\frac{L_U}{L_S}\right)^{\frac{1}{\sigma}}$$

Step 2: Take the natural log of both sides of the equation

$$Ln(\frac{\frac{Wages_S}{Wages_U}}{\frac{\alpha}{1-\alpha}}) = Ln(\left(\frac{L_U}{L_S}\right)^{\frac{1}{\sigma}})$$

This step would then create the following equation:

$$Ln(\frac{\frac{Wages_S}{Wages_U}}{\frac{\alpha}{1-\alpha}}) = \frac{1}{\sigma} * Ln(\left(\frac{L_U}{L_S}\right))$$

Step 3: Isolate σ

$$Ln(\frac{\frac{Wages_S}{Wages_U}}{\frac{\alpha}{1-\alpha}})/Ln(\left(\frac{L_U}{L_S}\right)) = 1/\sigma$$

Step 4: Solve for σ

$$1/Ln(\frac{\frac{Wages_S}{Wages_U}}{\frac{\alpha}{1-\alpha}})/Ln(\left(\frac{L_U}{L_S}\right)) = \sigma$$

<u>Appendix Two:</u> Calculating unskilled labor to skilled labor projections

The data for this procedure was taken from the National Center of Education Statistics website which displayed data from Current Population Survey Annual Social and Economic Supplement. Data is from the years 2008-2017.

Step 1: Calculate the average annual change for percent of population with bachelor's degree

$$\frac{2017\ \% - 2008\%}{10} = average\ annual\ \%\ change$$

Step 2: Add projected annual change to 2017 value to calculate 2020 projection

$$2017\ \% + (average\ annual\ \%\ change * 3\ years) = 2020\ \%$$

Step 3: Subtract 2020 % with a bachelor's degree from 100 % to calculate percent of unskilled labor

$$100 - (2020\%\ with\ bachelor's\ degree) = \%\ unskilled\ labor$$

Step 4: Divide % unskilled labor by % skilled labor

$$\frac{2020\ \%\ unskilled\ labor}{2020\ \%\ skilled\ labor} = 2020\ unskilled\ to\ skilled\ abor\ ratio$$

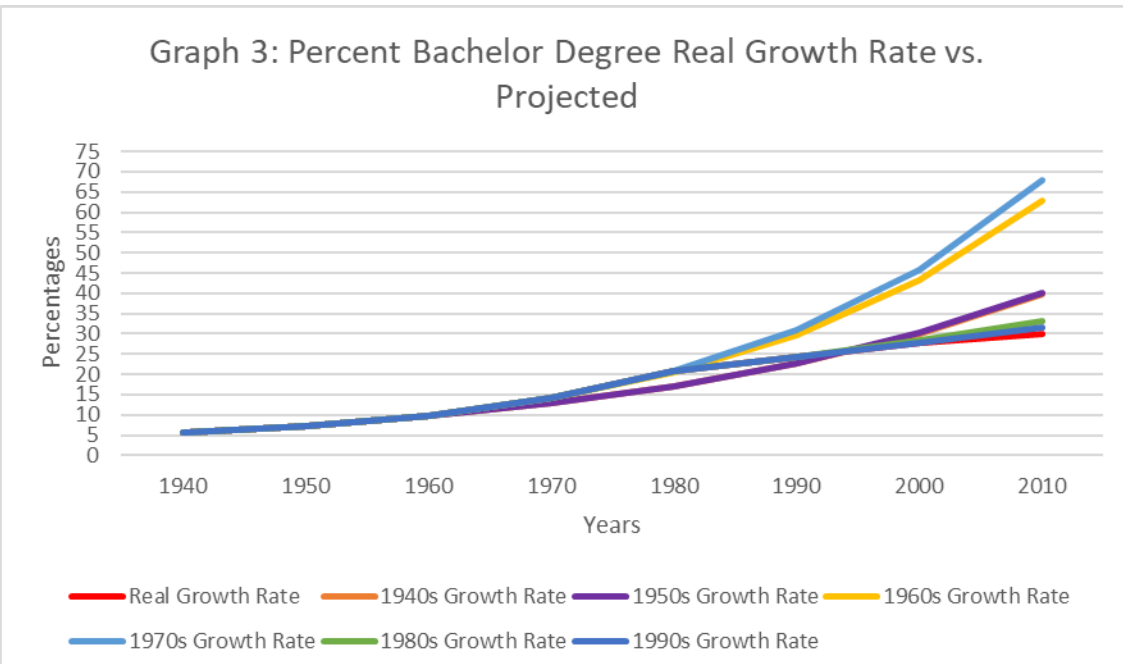
This process was followed for the projections for the years 2025, 2030, and 2040. The only difference was the number of years multiplied in step 2.

Supplementary Tables

<u>Percent of US population with a Bachelor's Degree (2008-2017)</u>

Table 3: Percent of US population with a Bachelor's Degree or higher	
Years	% of Population with Bach Degree or higher
2008	29.4
2009	29.5
2010	29.9
2011	30.4
2012	30.9
2013	31.7
2014	32
2015	32.5
2016	33.4
2017	34.2
Source: Current Population Survey Annual Social and Economic Supplement	

Table 3.1: Percent of US. population with Bachelor's degree or higher	
Years	% of population with Bach. Degree or higher
*2020	35.64
*2025	38.04
*2030	40.44
*2040	45.24
Source: Current Population Survey Annual Social and Economic Supplement	



Supplementary Table 4: Projected and Real Growth Rates for Percent of Population with a Bachelor's Degree					
1940 Growth Rate predictions	1950 Growth Rate predictions	1960 Growth Rate predictions	1970 Growth Rate predictions	1980 Growth Rate predictions	1990 Growth Rate predictions
5.5	5.5	5.5	5.5	5.5	5.5
7.3	7.3	7.3	7.3	7.3	7.3
9.7	9.7	9.7	9.7	9.7	9.7
12.9	12.9	14.1	14.1	14.1	14.1
17.1	17.1	20.5	20.9	20.9	20.9
22.7	22.8	29.8	31.0	24.4	24.4
30.1	30.2	43.3	45.9	28.5	27.8
39.9	40.2	63.0	68.1	33.3	31.7
Source: National Center for Education Statistics					
Note: Highlighted sections are projections					