Labor outcomes, education, and inequality in the age of automation

We are in the midst of an automation revolution. Automation refers to the increasing amount of labor and tasks that machines and computers can conduct. While this may add to the ease of our lives through the negation of laborious tasks, when it comes to our economy, automation is a double-edged sword. There have been several other revolutions in the past century or so like the scientific revolution, the electronic revolution, the digital revolution, but there is a key difference that makes the automation revolution distinct from the others. While the former revolutions almost exclusively allowed for new technology to compliment labor, automation both compliments and replaces labor. Whether or not automation compliments or substitutes labor is largely thought to be based on what type of work a laborer performs. The effects of automation's replacement effects could be astounding. In the following essay, I will evaluate literature that focuses on the labor outcomes caused by automation, how to combat the unwanted economic outcomes of automation through education, inequality issues that can arise through not only automation but also the solutions to its negative effects, and lastly describe and analyze policy proposals aimed at automation and inequality issues.

Automation has many strengths: it cheaply replaces the labor that can be easily automated. This removes a lot of monotonous tasks, but it also can remove ones that require great manpower. Take for example farming. In the United States, agriculture is a big industry, that historically needed a lot of man and animal power to sustain, but in modern day is highly automated. Farming is also considered a low-skilled job. Other low-skilled jobs include assembly line manufacturing jobs or simple clerical work. A lot of times these low-skilled work requires little training for humans to conduct, little cognitive ability, and lends itself more to physical labor. However, automation also has limitations where humans can excel. Machines, although exceptionally good at one or a few tasks, and getting better at slightly more complex work, struggle with tasks that require creative intelligence, discretion, and problem-solving skills. This creates a human comparative advantage in the workforce for jobs that rely on these attributes. Not only can machines not yet fill these functions at a desirable level, but often human comparative advantage also compliments automotive technologies in "non-codifiable." High-skilled laborers, ones with high level of education or technical instruction, tend to compliment automation technology better because of their raised human capital and skill applicability. Furthermore, tasks that are attached to geographic locations (like haircuts or maintenance) are also difficult to automate not only because of the creativity and judgment involved with each scenario, but it is also located in a time and place as opposed to something that is mass produced or can be updated or analyzed by a computer at any point in time (Autor). Because of this, the type of job that people have is extremely important to evaluate the causes of automation on the person, and even more broadly industries.

To many, automation threatens peoples' livelihoods and jobs. Simple tasks can be automated while higher skill jobs have yet to be automated or are as easily automated. Furthermore, according to a paper authored by Prettner and Strulik, (2020) low-skilled workers' wages don't increase due gains from the additional technology like high-skilled workers' wages do, as a product of high-skilled workers' increased productivity and complementary skills to new technologies.

However, even though automation can destroy demand for labor, there are still some positive aspects of it on the labor market. One, more optimistic, outlook at the destruction of labor is that although machines and robots substitute labor, they don't necessarily substitute an entire job. Automation is usually done by a machine which is extremely consistent and efficient at one task, but jobs often require several different tasks. Therefore, although labor is replaced, laborers who are apt or well trained at other tasks, specifically ones that aren't yet or can't be automated can continue investing more time into those groups of tasks that are not automated or codifiable (Arntz, Gregory, & Zierahn). The idea of thinking about work as a package of tasks, as opposed to a single thing a laborer does allows us to think about what types of tasks society should emphasize for their populace to compliment new technologies.

As previously stated, there are more positive effects from automation on jobs, because work can also be created from automation. In the Industrial Revolution many artisans were put out of work by factories and machines, but more jobs were created in cities working in factories. Similarly, during the Scientific Revolution, where we discovered and gained control of not only new forms of power, which displaced a lot of need for animals in the economy and their associated industries like farriers, it also opened new forms of communication like telegraphs. These new technologies gave birth to new fields of science but also of technical expertise like engineers, maintenance workers, and communications operators. From the 1950s to the turn of the millennia, the Digital Revolution led to the creation of new electronics from televisions and telephones to home computers an Internet. However, now, in the Artificial Intelligence Revolution we have powerful computers that can do analytical and clerical work and advanced medical equipment can do tasks with incredible precision and accuracy. If we assume that new jobs and tasks are created at the same rate as automatized technologies, then the equilibrium for wages and job participation will stay the same in the long run (Acemoglu & Restrepo). However, another key assumption is that high skilled laborers compliment new technologies and tasks, while low skilled workers are substituted. The effect on inequality is therefore twofold, because as compliments, high skilled workers rise in demand and the demand for low skilled workers, because they're substituted, decreases. This widens the gap between high and low skilled workers. However, if more people in an economy have high level skills, the difference in scarcity of high and low skilled workers reduces inequality. Again, the need for education, to graduate workers from low to high skilled workers, is imperative to benefit from automation and not be harmed by its substitutional properties.

Although education is heralded as the great protector from automation, certain fields in high level education are not as safe as others. Occupations with more social practices and skills have seen sustained growth in the past few decades, while STEM fields have seen declines in employment growth in the United States (Deming). The paper estimates that STEM fields have shrank by .12 percentage points as share of the labor market, while other professional jobs, with similar number of years needed for proper education, grew by comparative share in the market by over 2 percent in the same timeframe. This further drives the point of social and creative intelligence as comparative advantages versus automation being imperative, maybe even more than education at certain points.

In a Pearson study dedicated to, in part, evaluating the important variables that predict job growth in the United States' and the United Kingdom's economies, skills and knowledge of physics, programming, and engineering ranked 65^{th}, 66^{th}, 67^{th}, respectively (Bakhshi,, Downing, Osborne, Schneider). This was out of 120 possible variables—which puts them in the bottom half. Granted, the scaling on the estimation was not linear, and their effects are still positive, unlike a lot of physical skills or abilities like stamina (85^{th}) and multi-limb coordination (104^{th}). Regardless, the rank of applicable STEM skills and knowledge is outranked heavily by other skills at the top. The top five skills, in descending order, that contribute to positively estimating future growth in the coming few decades are learning strategies skills, knowledge of psychology, instructing skills, social perceptiveness skills, and knowledge of sociology and anthropology. Ranking sixth is education and training. Several of the top skills include communicative skills and management skills. These estimates of future likelihood of job growth in the economy are agreeable with Deming's findings from the past decade or so in the fact that social skills are large contributors along with education and training, and also align with diminished, low-skill jobs that automation substitutes that require more physical skills as opposed to social or cognitive ones.

The research by Deming and Bakhshi, Downing, Osborne, and Schneider can further be applied to the tasked-based outlook on automation by Arntz, Gregory, & Zierahn. In the case of Deming, while a supercomputer and Artificial Intelligence might be able to replicate a high-skilled laborer's analytical skills, that is just one task it can do. If another part of the job were then explaining the findings to fellow researchers, students, or clients, a laborer with better social and communicative skills would be harder to replace and less substitutable than one with little skill in communication. As for the latter example, although certain aspects of jobs are estimated to show the likelihood of growth, no job relies on just one of the 120 abilities. For example, an engineer would not only need the technical knowledge of engineering, but they would also need coordination and complex problem-solving skills. This is just a small, limited example for one job, let alone a whole economy.

The effects of automation on the economy and labor markets are the primary reasons automation has such a large effect on people. Families and individuals develop livelihoods around their jobs which are sorted by their aptitudes and education. Though the economy is where initial impacts lie from automation, this bleeds into other parts of life. Policy is needed to help individuals adapt to the evolving economy and technological systems, and the primary tool is education. We've already seen that education has importance in determining whether laborers are complimentary or substitutes, but what we educate people in—not just how much a society educates someone—is important as we examined in the Deming research paper which compared traditional, analytical stem job growth to job growth that required both high analytical and social skills.

Education

As seen in the research done in evaluating employment and the economy, education is a huge determiner of success in the past and also in the age of automation. A person's educational status can make them either compliment or substitute to automation, AI, and machines.

Automation is a double-edged sword. The productive benefits for firms are astounding and could cheapen the costs for consumers immensely. However, there is bound to be job loss at some time. This job loss is predicted to affect low-skill workers in the near future. If skill is innate to people in society but in varying degrees, some will inevitably be left behind, unless they use education—education that is high quality and transformative—to augment their skill set to higher skill levels (Bentaouet, Patrinos). Education can play a massive role and is the main variable that determines whether automation will be advantageous or not for a given country. Educational investment also is more important for middle income countries because their economies are usually highly susceptible to automation and their people generally attain lower education than those of higher income countries. Both amplify the negative effects of automation.

David Autor, in his paper *Why are there still so many jobs? The history and future of workplace automation* described two types of jobs: "manual" jobs and "abstract" ones. "Manual" jobs are usually those which require either manual labor to conduct simple tasks or clerical jobs that require little technical skill or training, while “abstract” work “are characteristic of professional, technical, and managerial occupations,” (Autor). This includes problem-solving creativity, judgment, interpersonal skills, inductive reasoning while also pulling from a well educated and highly skilled technical background. “Abstract” jobs, as described by Autor, fits within the definition of what jobs saw growth in the economy in Deming’s research analysis. One thing that is crucial to note however are the social skills listed. While Autor underscores the importance of technical background, according to Deming’s findings, background is not enough—communication is a key part of what makes safer, “abstract,” jobs succeed versus not only low-skilled workers but also highly educated workers with only analytical skill sets. “Abstract” jobs are identifiably high-skilled and “manual” jobs low skilled. This causes polarization in the job market with one class of people being highly complimentary to emerging fields, technology, and industries while others are substitutable. This again highlights the importance of education for the future. Our economy has already seen a proportional shrinking of low skilled jobs and even analytical jobs. As capital increases and technology improves, educating more people into “abstract” jobs may be critical to national economies to capitalize on automation’s positive effects.

In 2017, Prettner and Strulik researched how and research and development (R&D) approach to automation could predict outcomes for laborers in the future for technology, education, wages, and inequality, in *The lost race against the machine: automation, education, and inequality in an R&D-based growth model*. Firstly, it assumes that there are two types of laborers high- and low-skilled which are compliments and substitutes to new technology respectively. This is a departure from other R&D models that only assume that technological change augments labor as opposed to possibly replacing it. According to their model, because high skilled workers are compliments to new technology, their wages increase due to a wage premium that is proportional to technological growth. This will cause an increase in high-skilled workers due to the skill premium and more incentive to attain higher levels of education. Meanwhile, increasing wages for high-skilled workers who not only act as compliments to technology but can also further its advancement, increases inequality between worker groups via the skill premium. Because the high-skilled worker skill premium is proportional to level of technology, as technology increases, so does the skill premium, and therefore so does the inequality between high- and low-skilled workers. As technology increases over time, it continues to substitute low-skilled jobs. As people who cannot attain educational status required for high-skilled jobs stay at their low-skilled status, they are eventually forced out of the economy. This causes labor force participation in the population to decrease and proportion of working population as high-skilled to increase.

Educational differences between men and women have been growing in the United States of America for decades now, but it is not females who are worse off. Since the 1950s, female Americans have graduated from high school, obtained some college level of education, as well as graduated with four-year degrees at higher rates the male Americans (Autor & Wasserman). With comparatively less educational attainment, males in the United States have suffered income losses over the years. Those who lose the most income on average are the least educated and least experienced of men. Even men attaining some level of college but not attaining a full degree have seen income growth losses throughout their working careers. This change in economic outcomes has been across demographics for both men and women. Black and White male participation in the labor force since 1972 has decreased by several percentage points while Black and White women's population share of the labor force has increased in the same time period to over 50%. It is worth noting still that the decrease in the black male labor force was greater than White males, and White women's growth in the labor force was greater than Black women, though black women are still more likely to be engaged in the workforce.

Education is obviously thought to be a key in allowing humans to be compliments to automation. Not only could it determine future wages based on technical growth as theorized in Prettner and Strulik's R&D model, but it has already shown current effects on labor outcomes for low- and high-skilled workers, and between gender and racial demographics. While there are still low-skilled jobs, job growth and income growth lie within high-skilled jobs. That being said, this creates polarization—haves and have-nots. With high-skilled workers able to capitalize on skill premiums, unlike unskilled workers, wages between classes of workers diverge and inequality increases.

Inequality

Inequality has been an underlying symptom of several of the research papers discussed in this literature review. Inequality has several other side-effects unto its own the can effect quality of life. Some inequality, as it pertains to automation, can be attributed to the different working classes of high- and low-skilled workers as they relate to new technologies. This happens both on the demand side as high-skilled workers serve as complements and from a research and development approach (Prettner and Strulik). Men in their prime earning years, who are historically the main providers of income for their families, have low labor participation rates, which can cause family incomes to suffer (Autor and Wasserman). But the inequalities do not stop at just job type—it runs deeper into education. Education sorts people into jobs that they have the proper training and skills for. In the past half century, graduation rates, particularly for men, have stagnated in the United States and the rate men attaining higher education is far below women. This puts men disproportionately into low-skilled jobs automatically and makes them more likely to be replaced by automation. Furthermore, as discussed in Autor’s and Wasserman’s *Wayward sons: The emerging gender gap in labor markets and education,* Black men have suffered more from labor participation than White men.

Focusing on higher-order cognitive skills in education does help reduce inequality between low-skilled workers and their high-skilled counterparts (Bentaouet, Macdonald, Patrinos). As estimated by a linear regression, if educational systems not only teach young people cognitive skills needed to for classic analysis, math, and reading skills, but also emphasized “non-cognitive skills, including creative-intelligence, social, intelligence, and advanced perception,” then inequality between the two working classes could be reduced by up to 3%. This is because the increased value of education allows people to adjust from low-skilled, middle-, and high-skilled individuals in accordance with automation. The caveat with this educational inequality mitigation is that schooling and training systems must be wide-spread and proficient enough to allow mass changes of skill for the population.

Even if education is able to mitigate some of the inequality between high- and low-skilled working classes, it won’t be able to do everything. Inevitably, automation will cause greater wage inequality. Because automation technology substitutes low-skill tasks, wages for those low-skilled jobs are suppressed (Acemoglu and Restrepo), however high-skilled workers’ wages are not suppressed. In *Low-Skill and high-skill automation,* Acemoglu and Restrepo argue that although laborers may experience lower or suppressed wages, in the short run there can be offsetting forces that help create jobs and demand. First is that with new capital, the productivity effect takes place which makes all factors of production—bot high- and low-skilled workers more productive and gives opportunity to boost wages. However, in the short run, the productivity effect can be diminished by growth in demand which would increase the price of capital but also make labor comparatively cheaper. Acemoglu and Restrepo also argue that because capital's cost is constant in the long run that wages will grow because of the productivity effect over the long run. This is a pretty stark disagreement with Prettner's and Strulik's (2017) R&D model which hypothesized that technological growth caused inequality. Through the model, Acemoglu and Restrepo also note that its possible for high-skill work to be automated. This is something possibly seen in Deming's work where highly educated, analytical stem jobs saw a decrease in labor share in the economy over a roughly twenty-year period. If low-skill automation can substitute low-skill workers, then high-skill automation that uses cutting-edge machine learning and AI can logically replace high-skilled workers. This is still to say that high-skill workers are still compliment to low-skill automation. This leads to the conclusion that low-skill automation causes an increase in inequality between high- and -low-skill workers, while high-skill automation decreases inequality.

From a inequality perspective, it is also important to limit volatility and economic crises in the age of automation. Economic downturns have showed an acceleration in firms investing in automated technologies (Hershbein and Kahn). Therefore, to give people opportunity to retool themselves and invest in their own human capital, it is within government interest to limit economic crises not just on the strain they cause the people and their economy but also because during that period, the rate of automation increases. This creates inequality that is not only caused by recessions but skill premiums from automation at the same time. This is especially important to consider because in the course of just over a decade, the Great Recession rocked the world economy only to be followed shortly after by the COVID-19 pandemic and its respective economic shock to the global economy.

Inequality is a systemic issue regarding automation. Not only does it show up in work outcomes, it appears in education—a key tool in mitigating adverse effects of automation, too. Furthermore, protecting economies from shocks might have unseen benefits other than just drops in demand and supply, as it pertains to inequality.

Policy

Approaching solutions to automated displacement can be aided by policies. Two of the biggest places where policy can improve outcomes is inequality, both in wages and education, as well as the promotion of education. It's important to reiterate that the educational promotion should be in areas that humans have a competitive advantage and have seen growth. Education that emphasizes only analytical skills—and not social skills, creative intelligence, problem solving, judgment, and other forms of comparative human advantages—will suffer from diminished labor force outcomes. Secondly, for individuals who cannot attain higher levels of education, implementing efficient taxes that gain revenue from displacing forces could have a two-fold effect: lowering demand for automation capital and increasing tax revenue to lower inequality between low- and high-income workers.

As for tax policy, Prettner and Strulik predict that a capital tax used to subsidize education would lower the demand for high-skilled workers and reduce research and development, therefore leading to a decrease in high-skilled workers. Research and development can help us find new technologies and potentially create new jobs and industries in the future. Meanwhile, we know high-skilled jobs compliment automation technology and have increased wages with technical advancement. Because the capital tax would decrease demand for capital, there would be a decrease in high-skilled workers used to work with capital as well as less returns on creating new capital through research investment. Additionally, a robot tax cannot fix the long run growth issue of automation (Gastiger and Pretner): When jobs are automated, wages decrease, which then decreases capital to be invested and disallows economic growth. The tax can aid in other ways, like increase government funds, but it cannot enable long run growth alone. However, Gastiger and Pretner then argue that a tax on wages would cause a higher demand for high-skilled workers, and increase the premium for high-skilled workers, thus increasing their wages. This is because the absence of a capital tax would not decrease demand for automation capital or investment in research and development, therefore demand for automation technologies' complement, high-skilled workers, would also not decrease. A flat wage tax used specifically to fund higher education and aid in transforming low-skilled laborers to high-skilled laborers, however, would increase wealth inequality and be regressive, because taxes from low-skilled laborers would go toward subsidizing high-skilled workers' educations. This gap in education of workers as well as low and high-skilled workers' incomes could potentially be closed with investment in education now (Bentaouet, Macdonald, Patrinos), as opposed to trying to re-tool adult laborers later in life with vocational programs. This is because the things that are hardest to automate are higher orders of thinking like "creative intelligence, social intelligence, and advanced perception." If, as a society, we can make our education systems more efficient in these areas, human comparative advantages against automation can be maintained by more people and alleviate inequality between different types of workers.

There's also the argument that a robot tax will always reduce wage inequality between labor classes. This is more akin to the Prettner and Strulik view of a robot tax, however due to increase cost of capital for firms and decreased demand for high-skilled individuals as well as a decrease on skill premium, a robot tax would lessen the wage inequality (Zhang). This hypothesis assumes that elasticity of substitution between capital (i.e., automation technology) and low-skill workers is high enough to cause significant changes in employment and wages upon institution of a robot tax.

Automation does not just cause inequality between types of workers, but it is also causing a disparity between genders. In a study that analyzed both micro and macroeconomic in high-performing economies, there was found a significant decrease in prime-aged males in the labor force (Grigoli, Koczan, & Topalova). Through the study's regressions it estimated that repetitious labor was a key factor that led males to be uninvolved in the labor force, often through automation of jobs over time. In the same amount of time, women's involvement and labor outcomes in the same amount of time improved. Women's workforce improvements came mostly from improvement of educational outcomes and opportunities, policies engineered to help them engage in workforce, and structural factors, but automation still lessened the positive effects that of women's labor outcome growth. The research posits that while automation has negatively affected prime labor participation, specifically in men with routinized jobs, there are a few policies that can aid in limiting the detrimental effects of automation. It lists, "higher spending on education and active labor market programs, and access to more diverse labor markets, are associated with a smaller negative effect of technological change on participation," (Grigoli, Koczan, Topalova). Therefore, including incentives for working or programs that culturally reinforce work as important can be useful policies to pair with educational investment and investments in new industries that diversify a nation's economy.

Policy is an important tool to combat the woes of automation and can take several forms from taxes on capital and income; investment in emerging fields, industries, and education; as wells as social programs that encourage workers—specifically males—to participate in the workforce. Policy can help address not just problems within the economy and labor market, but it can also aid in inequalities between different workers and types of people.

Conclusion

In conclusion, automation, like several other scientific revolutions and eras before it affects several different parts of our society and creates problems for different people. Humans have complimentary skills and advantages over automation technology and machines, but in order to best utilize those skills, we have to properly educate people from an early age and have them achieve high levels of technical and social knowledge to make them resistant to the detriments of automation. Automation has substitutional properties that are detrimental to low-skilled workers. With high-skilled workers gaining a premium from complimentary skills, and low-skill workers' wages depressed by automation, inequality arises as a serious problem between skilled and unskilled laborers. Making investments in educational institutions and social safety nets for those who do not or cannot attain skilled worker status is important for limiting inequality in the age of automation. In order to effectively do this, we need governmental policies that encourage people workers to attain higher education and curb inequality.

Work Cited

Acemoglu, D., & Restrepo, P. (2018). The race between man and machine: Implications of technology for growth, factor shares, and employment. *American Economic Review*, *108*(6), 1488-1542.

Acemoglu, D and Restrepo,P., Low-Skill and high-skill automation, *Journal of Human Capital*, volume 12, Number 2, pages 204-232, 2018, https://doi.org/10.1086/697242

Arntz, M., T. Gregory and U. Zierahn (2016), The risk of automation for jobs in OECD countries: A comparative analysis, *OECD Social, Employment and Migration Working Papers*, No. 189, OECD Publishing, Paris, https://doi.org/10.1787/5jlz9h56dvq7-en.

Autor, D H. 2015. Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspectives*, 29 (3): 3-30.

Autor, D. & Wasserman, M. (2013). Wayward sons: The emerging gender gap in labor markets and education. *Third Way Report*, *20013*.

Bakhshi, H., Downing, J. M., Osborne, M. A., & Schneider, P. (2017). *The future of skills: Employment in 2030*. Pearson.

Bentaouet K. R Patrinos, H. A., Automation and Labor Market Outcomes: The Pivotal Role of High-Quality Education (June 14, 2018). World Bank Policy Research Working Paper No. 8474, Available at SSRN: https://ssrn.com/abstract=3238308

Bentaouet K. R., Macdonald, K. and Patrinos, H.A. (2021), The role of education in mitigating automation's effect on wage inequality. *Labour*, 35: 79-104. https://doi.org/10.1111/labr.12187

Deming, D. J. The growing importance of social skills in the labor market, *The Quarterly Journal of Economics*, Volume 132, Issue 4, November 2017, Pages 1593–1640, https://doi.org/10.1093/qje/qjx022

Gasteiger, E., & Prettner, K. (2020). Automation, stagnation, and the implications of a robot tax. *Macroeconomic Dynamics,* 1-32. doi:10.1017/S1365100520000139

Grigoli, F., Koczan, Z., & Topalova, P. (2020). Automation and labor force participation in advanced economies: Macro and micro evidence. *European Economic Review*, *126*, 103443. https://doi.org/10.1016/j.euroecorev.2020.103443

Hershbein, B, and Kahn, L. B. . 2018. Do recessions accelerate routine-biased technological change? Evidence from vacancy postings. *American Economic Review*, 108 (7): 1737-72. Accessed at https://www.aeaweb.org/articles?id=10.1257/aer.20161570

Prettner, K. and Strulik, H, The lost race against the machine: automation, education, and inequality in an R&D-based growth model (December 1, 2017). cege Discussion Papers No. 329, November 2017, Available at https://ssrn.com/abstract=3080967 or http://dx.doi.org/10.2139/ssrn.3080967

Prettner, K. & Strulik, H.. Innovation, automation, and inequality: Policy challenges in the race against the machine, Journal of Monetary Economics, Volume 116, 2020, Pages 249-265, ISSN 0304-3932, https://doi.org/10.1016/j.jmoneco.2019.10.012. (https://www.sciencedirect.com/science/article/pii/S0304393219301965)

Zhang, P. Automation, wage inequality and implications of a robot tax, International Review of Economics & Finance, Volume 59, 2019, Pages 500-509, ISSN 1059-0560, https://doi.org/10.1016/j.iref.2018.10.013.