Automation & Artificial Intelligence: Transforming the US Labor Market & Worsening Income Inequality

David Isaac Schlosser
Bard College

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David Schlosser

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DEDICATION

This thesis is dedicated to my loving family. Thank you for being there for me through all of the ups and downs.

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I would also like to recognize my boss, who has become more of a mentor to me, Mitchell Osak. More than just enlightening me to the effects of automation and artificial intelligence on the economy, Mitch taught me how to be a forward-thinker and the importance of recognizing "headwinds" before they come. This, among many other lessons, has helped me academically and will continue to guide me professionally after I graduate from Bard.

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Introduction

Artificial Intelligence (AI), Robots, and anything in between seems to be the hot topic when talking about the job market. Even if you simply type ‘Automation' into Google, the output will be an abundance of articles titled "Robots Are Coming For Your Job" or something along those lines. While we have been able to automate things for a long time, our progressions in the field of automation have been growing exponentially in recent years. Perhaps this is why there is a current wave of anxiety toward this subject. Nonetheless, relative to how prevalent it is becoming, many people’s fears are quite irrational, as they don’t really understand what our technological advancements are, and how they are going to affect them.

This essay serves to answer those two important questions: what is this technology and who is going to be affected and how. We will explain on a high level (without diving into complex computer science concepts and jargon) what automation and artificial intelligence are and what happens when they are combined. Next, we will make sense of why society is convinced that this technology will eventually replace them in the workplace and use a neoclassical framework to portray what may actually happen. And finally, we will look at the overall economic implications of being able to automate more and more kinds of labor, and provide policy recommendations to either stop or offset them. In no way are the concerns of many that artificial intelligence will be capable of replicating what they do for a living and will “take their jobs” totally farfetched. However, it is fundamental to build a framework for understanding this prevailing ideology in depth, so that we can understand it on a level that we can actually do something about it. But before we jump to conclusions, we need to understand what automation and AI are in the first place.

Chapter 1: What is AI and Automation?

It is evident that in general, people are aware of the fact that there is some sort of conflict between this thing called automation and the labor market. The trend of this topic's significance has gotten strong enough to the point where it has caught the attention of people who don't possess the same technical knowledge of people in the field of computer science. Therefore, if we wish to explore this in deeper detail, it is essential to first explain what this thing is that is supposedly going to take our jobs. After we define what automation and artificial intelligence are, it is equally important to distinguish between the two because most people use the terms automation and artificial intelligence interchangeably, when in reality, they are two totally different things. Although they are independent concepts, they do come together to create 'Cognitive Automation', which will also have a role when looking at the issue at hand (IBM).

1.1 Automation, artificial intelligence, and cognitive automation

Let us begin by looking at automation. The dictionary defines automation as "the technique, method, or system of operating or controlling a process by highly automatic means, as by electronic devices, reducing human intervention to a minimum" (Dictionary.com). For our use, we will define it as any hardware or software that works mostly automatically with minimal human intervention. The reason why it is so important to allow for some human intervention is because, as we will explore later on, that automation doesn't have to completely replace human labor for it to have an impact on the job market. For example, automation that can work with humans and in turn make them more efficient, increase their output, etc. will still have a significant impact on labor and specifically, demand for human labor. Another key component of automation as it stands on its own is that humans are necessary on the front-end for the hardware or software to perform the task as it is supposed to. For example, think of an alarm. If one wants to wake up at 8:30 am in the morning, he/she will have to program the clock to go off at that time. The process of the alarm going off at 8:30 am is a form of automation. The alarm itself is incapable of programming itself to perform its task, however, with human input, it can automatically. As we will reveal later on, unlike artificial intelligence, automation can and does pose a threat to certain types of labor on its own (Ideyatech).

Next, let's talk about artificial intelligence and define what it is. According to Springer's *Handbook of Automation,* artificial intelligence is when non-living machines are able to replicate intelligent behavior; something that once could only be found in humans and animals. Some examples of the tasks that computers are able to imitate are seeing, learning, using tools, understanding human speech, reasoning, making good guesses, playing games, and formulating plans and objectives. As you can see, these are jobs that humans perform and earn a salary for in the labor market, and the better machines get at performing them, the more incentive business owners may have toward "employing" computers instead. Artificial intelligence needs a platform (hardware or software) for it to express itself and function. Therefore, it does not pose a threat on its own like automation does. However, when paired with automation, artificial intelligence can constitute a risk to parts of the labor market that we have never seen before.

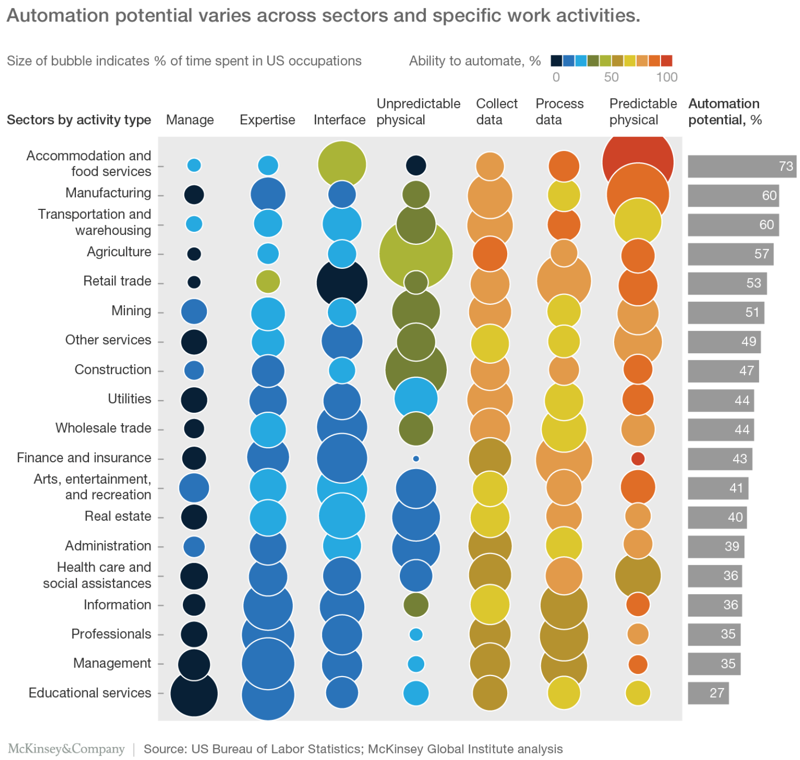
The product of automation and artificial intelligence is what most people fear when they think of robots taking their jobs: Cognitive Intelligence (Deloitte). There are two reasons why people are recently fearing our development in his space: 1) our capabilities within it have grown exponentially in recent years and 2) this means that we can replicate human behavior and tasks that were always deemed “untouchable” by technology. If we go back to the example of the alarm, an example of Cognitive Automation would be if the alarm was able to learn from one’s sleeping patterns and program itself to go off at the correct time and perhaps even at the optimal time once the user has had the optimal amount of sleep for the night. We can go even further and say that cognitive automation could allow the watch to communicate with other devices such as a smartphone, to extract data on the user’s schedule, the weather, etc. to make decisions on when to permit the alarm to go off and provide recommendations to the user based on these things (how to dress, how much time is left before he/she must leave for work, options on how to spend that time, etc.) This is a basic example of how automation (the watch) and artificial intelligence (the ability for the watch to act intelligently and make intelligent decisions) can come together to create cognitive automation. This example by no means would replace anyone job; in fact, the development of this concept would even create some. However, the notion of cognitive intelligence can be applied to many scenarios that do directly impact the labor market, and we will explore these later on in this thesis.

1.2 How do these concepts relate to economics?

So, why should we care and why is it important to apply these technological advancements to the workplace? Other than the aforementioned trend that robots are supposedly going to take all of our jobs, there are several real implications of our technological advancements in the economy. First, while it is probably impossible for automation and AI to take all of our jobs, there will certainly be (and we have already started to see it happen) be certain types of labor that can be replicated by technology, and therefore cause new waves of "technological unemployment". Obviously, not all labor is the same, so we will section the labor market into various segments so we can obtain real forecasts on how new technology will affect employment within them. Specifically, the type of work in the economy will be segmented into 3 categories: low, medium, and high-skilled labor, and we will analyze how automation and AI have impacted the employment within each and attempt to forecast how it will be affected as we advance. Although we will use these three types of labor for traceability, it is important to note that there are more nuances in the types of labor that exist in the economy.

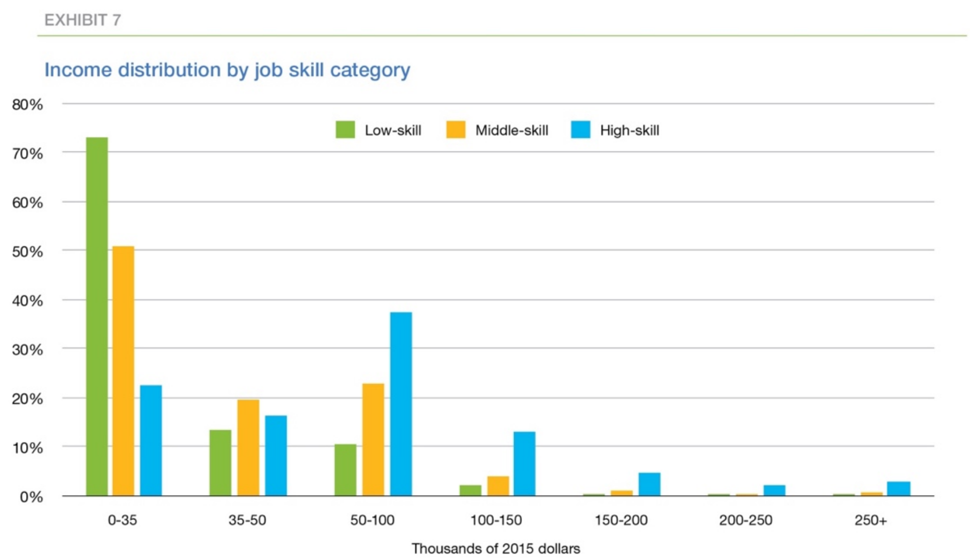
Another severe economic issue that can ascend from our technological progression is the large, and growing level of income inequality in the United States. The connection between technological unemployment and income distribution derives from my initial hypothesis that in our current state and in the short-run we are and will be able to automate almost all jobs considered low-skilled. The following graphic by McKinsey & Company can be used to confirm this hypothesis:

Figure 1-1



The above graph, which uses data from the US Bureau of Labor Statistics accurately confirms our ability to automate low-skilled jobs, like predictable physical labor, across a variety of industries. The more leftward on the graph the activity type, the more skill is required to complete it. Our ability to automate more leftward activities on the graph has been growing at a rapid pace and will continue to do so in the long-run. But our ability to automate low-skilled activities on the right is alarming, as in most industries we are currently able to automate more than half of jobs. The following graph can be used to confirm that our ability to automate low-skilled work is indeed an income inequality issue. The bottom end of the income distribution, the end that we are trying to protect and make better off in order to reduce income inequality in the US, is mostly populated by low-skilled workers:

Figure 1-2



Source: CPS 2016 Annual Social and Economic Supplement Survey. Steven Ruggles, Katie Genadek, Ronald Goeken, Josiah Grover, and Matthew Sobek. Integrated Public Use Microdata Series: Version 6.0 [Machine-readable database]. Minneapolis: University of Minnesota, 2015.
Note: Job Skill Category follows David Autor, "The Polarization of Job Opportunities in the US Labor Market," The Hamilton Project, April (2010).

As you can see, a huge majority (70+%) of low-skilled workers earned less than $35,000 in 2015 (Freddie Mac)**.** Income inequality is an enormous problem in the United States, and if capitalists are able to replace all low-skilled work with a cheaper, more efficient option, namely automation, and AI, that would only make this matter dangerously worse.

While robots will not take all of our jobs, there are real economic concerns that we need to be made aware of. This thesis aims to build a framework to explain the effects of one of the main issues, technological employment, in the three types of labor, and reveal how much of the labor market is vulnerable to these technological changes. If the low-skilled workforce will suffer the bulk of the consequences, this will have a detrimental outcome on income inequality and the US economy as a whole. We will now begin to attempt to answer these questions.

Chapter 2: Building a Framework for Applying AI and Artificial Intelligence to the Labor Market

2.1 Labor Demand

At the end of the day, the impact of automation and artificial intelligence on employment will come down to its effect on labor demand. Labor demand is the amount of labor a firm is willing or seeking to hire to achieve a certain level of output. This is the best approach at understanding how our technological advancements will affect the labor market because if we can observe that this technology will drive labor demand down, we can conclude that it will, in fact, cause technological unemployment. Otherwise, if the labor demand within a segment of the labor market is unharmed by our technological development, we can hypothesize that we are/will be unable to replicate such labor, and as such we will need to employ the same amount of humans to perform it.

Before we begin to build a model with complex functions and graphs, it is important to lay out the foundations of a neoclassical labor model, so that we can not only have a starting point to build from but understand the assumptions and boundaries that we can work within. First, firms simply hire (whether it be humans or capital) as "middle men". In other words, firms do not blindly hire units of input for the sake of filling a spot. Rather, they hire in order to fulfill the existing demand of consumers. Therefore, firms will hire up until the point that they can produce the amount of goods/services that there is a demand for because they are *profit-maximizing;* any additional units of input from this point on will by nature sway the firm away from the profit-maximizing point. We will get more in depth on this later.

2.2 The production function

Evidently, since production is the fundamental driver for firms to employ, the next most important notion to look at will be a firm's *production function*. The firm's production function is a measure of a firms output (*q*) as a function of a combination of two inputs: 1) Labor (*E)* and 2) Capital (*K)*, written as:

$$[1]\quad q=f(E,K)$$

It is easy to get the sense that this is an optimal measure of output given the question we are trying to answer. For example, if firms can produce the equivalent output level *q* at a lower cost, with a new combination of *E* and *K* that replaces human workers with more capital, the effects of automation on employment will, in fact, be a negative one. Again, once we are done laying out the framework, we will dive deeper into this issue.

The most important concept in regards to the production function is the concept of *marginal product.* Marginal product measures the change in production that results in an increase of a single unit of input. For example, the marginal product of labor is the additional output gained from hiring one more worker and can be labeled as (MP_e). Therefore, the marginal product of capital (MP_k) is the additional output gained from purchasing an additional unit of capital. Marginal product abides by the *law of diminishing returns,* which means that the marginal unit of either labor or capital will increase output but at a decreasing rate. Hence, an additional unit will increase Q, but less so than the previous unit. Calculating and analyzing these measurements is imperative to answer our question because it is what firms use to gauge their hiring decisions.

Before we explore how firms use marginal product to make decisions, we first need to lay out a few assumptions about how firms operate and the environment that they operate in. First off, in this framework, we will assume that prices are fixed because firms compete in a perfectly competitive environment and are *profit maximizing.* This means that firms are guided only by profits when making decisions. Profits are equal to total revenue minus total costs. Therefore, in our framework, we can equate profits as:

$$[2]\ Profits = pq - wE - rK$$

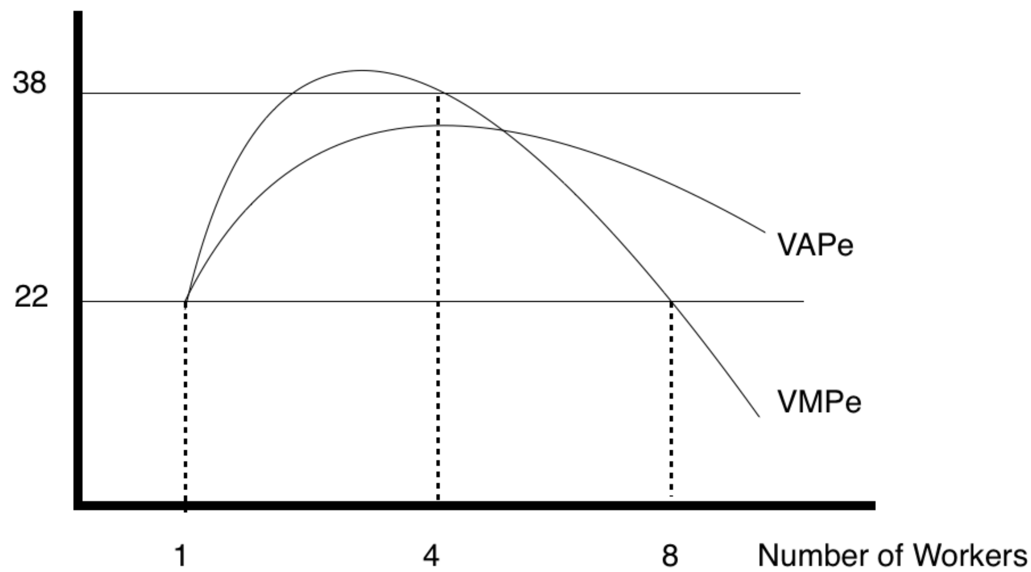
Where (*pq)* is price times quantity (or revenue), (*w)* is the wage rate, and (r) is the price of capital.

2.3 The short-run hiring decision

Now we can begin to explore how firms use marginal product to make decisions in the short run. In the short-run, we assume that firms cannot change their level of capital and it is fixed. This is because increasing or adding more capital takes time and is expensive. Since this notion is extremely confining, especially for this thesis, which seeks to explore the potential substitution of employment for new capital, the bulk of our analysis will be done in the long-run. Nonetheless, it is important to briefly derive how firms operate in the short-run, so we can better understand our current situation in terms of the labor-capital substitution decision and can obtain a better starting point to compare with our forecasts for the long-run or the "future state" as we will call it.

Since firms can only change output by increasing or decreasing the amount of workers they have in the short-run, profit-maximizing firms will fire up until the wage rate (*w)* equals the *value of marginal product of labor (VMP_e)*. VMP_e calculated by taking the marginal product of labor and multiplying it by price. This gives us the *value* in dollar terms that an additional unit of labor will provide the firm, which makes it ideal to compare to the wage rate. Graphically the short-run hiring decision can be visualized as such:

Figure 2-1



Since worker number 8 provides $22 worth of value to the firm but also cost the firm an additional $22, this is the profit maximizing point. This makes sense because of the law of diminishing returns, which tells us that the next worker will provide the firm with less than $22 worth of value, but will be paid the same, resulting in negative profit for the firm.

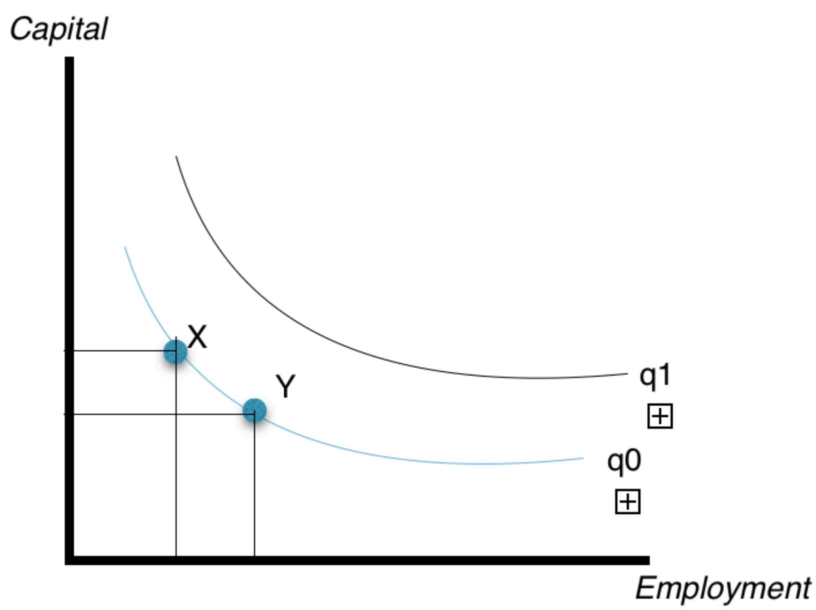
2.4 The long-run hiring decision

Now that we have established how firms make hiring decisions in the current state of capital, let us now explore how they make decisions when the assumption of fixed capital is removed in the long-run. Therefore, the firm must now choose not only the ideal amount of workers to maximize profit, but now the profit-maximizing point consists of an ideal combination of both labor and capital to achieve that level of output. To answer our question, we will mostly perform analysis in the long-run as it allows us to show how much companies are willing to substitute capital for labor over time as we advance technologically. For example, an early hypothesis is that as automation and artificial intelligence becomes better and more efficient at replicating human work, firms will opt to expand our equipment by hiring more capital instead of labor.

2.5 Isoquant curves

Since labor and capital are both variable in the long run, there are several combinations of *E* and *K* that produce the same level of output. Graphically, a set of combinations that render the same output takes the form of an *Isoquant curve* and have the following properties: they are downward sloping, convex to the origin, higher isoquants (that are further away from the origin) are associated with a higher levels of output (and in turn higher costs), and two different isoquant curves can never intersect. Isoquant curves can be visualized as such:

Figure 2-2



As previously mentioned, each point on the isoquant curve “q_0” results in the same level of output. In this case, combinations *X* and point *Y* lie on the same curve and thus result in the same output. However, at point *X,* the firm hires more capital to achieve this level of production, and consequently, at point *Y,* the firm does so by hiring more labor. The further away from the origin an isoquant curve is, the costlier it is to produce at that level. Therefore, it is evident that the combinations that lay on isoquant curve “q_1” are more expensive than those on q_0. The slope of the isoquant curve is given by the negative value of the ratio of marginal products:

$$[3]\ \frac{\Delta K}{\Delta E} = -\frac{MPe}{MPk}$$

The absolute value of the slope is called *the marginal rate of technological substitution*, which tells us the rate at which we substitute technology for labor; a measure very important to this thesis. The slope of an isoquant curve can also be measured by the negative value of the ratio of input costs (-w/r). This means that next dollar spent on a unit of either labor or capital produces the same output as if it were spent on the other. If this is true, money cannot be reallocated better and we are therefore in equilibrium.

2.6 Isocost curves

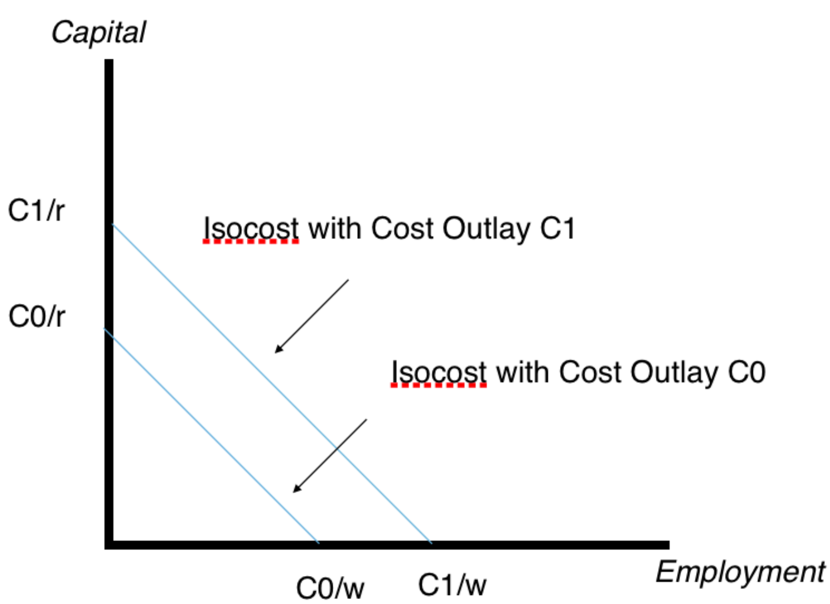
Until this point, we have been working under the assumption that firms always make decisions that maximize their profit. While this will always remain true, we will now add another key assumption: firms are also cost-minimizing. While these two assumptions are in some ways synonymous, including both has significant implications on the model. Since labor and capital are now both variable in the long-run and there are several combinations to achieve a profit-maximizing output, we now need to analyze which combination is optimal. The optimal combination is the mix of *E and K* that yields maximum output at minimum cost. In order to incorporate this into our framework, we will introduce the concept of an *isocost curve*. The cost of a given firm is represented by:

$$[4]\ C=w(E)+r(K)$$

An isocost line represents all combinations of *E* and *K* that are equally costly. Since this function is linear, the best way to plot it is to plot two extreme cases and connect to two points. The two extreme cases a firm planning on spending a certain amount of dollars can choose from is either to spend it all on capital and hire no workers, or hire only labor and purchase no capital.

In the first case, whose isocost line we will call "C_0", the firm will hire $\frac{Co}{r}$ units of capital (which is derived by solving for *K* in the above equation) and obviously no workers. This will give us a point laying on the Y-axis. In the second extreme case on the same isocost line, the firm will hire $\frac{Co}{w}$ workers, and no capital, which will give us a point on the X-axis. If we connect these two points, we can visualize isocost line C_0, where all points (combinations of *E* and *K)* on the line are equally as costly:

Figure 2-3



As an isocost line moves further away from the origin, the costlier the combinations are that fall on that line. In the example above, isocost line labeled "C_1" is therefore costlier than isocost curve C_1. Understanding how to calculate the slope of isocost lines will play an important role in the development of this thesis moving forward. It helps to rearrange the original cost equation C as follows:

$$[5]\ K = \frac{C}{r} - \frac{w}{r}E$$

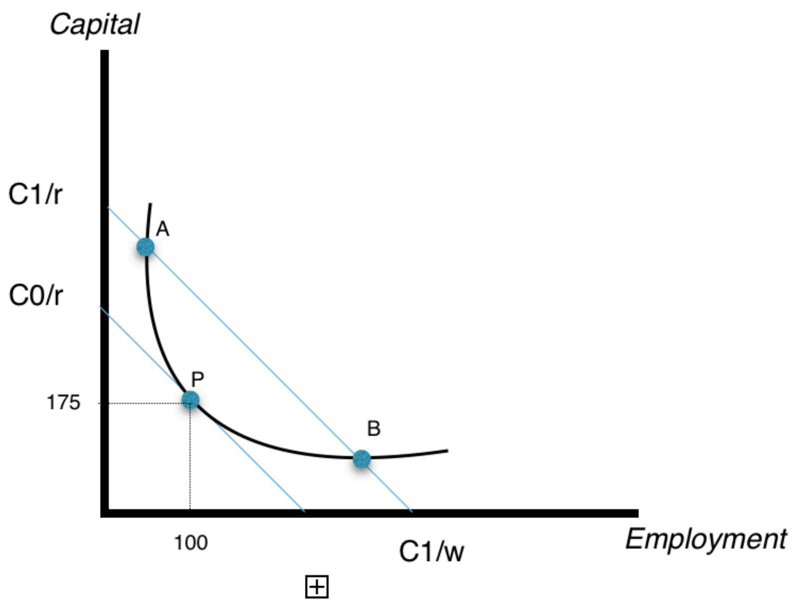
This equation now takes a standard linear form of "*y=mx+b*" with y-intercept $\frac{C}{r}$ and slope $-\frac{w}{r}$. The steeper the isocost curve, the cheaper capital is compared to labor and vice versa when it is flatter.

2.7 The long-run hiring equilibrium point

Now that we have a good understanding of isoquant and isocost lines, and that firms are motivation by both profit-maximization and cost-minimization, we can now calculate for the optimal combination of *E* and *K* that satisfies these motives. This equilibrium point is very important because the bulk of our analysis will examine how this point (the combination of capital and labor that a firm actually decides to employ) changes based on technological employment.

In short, the profit-maximizing, cost-minimizing, and therefore optimal combination is the point where the isocost curve is *tangent* to the isoquant line. When a line is tangent to a curve, it means that the line intersects it at one single point and not two. There is only one point in which a line intersects an isoquant curve. This point is the very bottom of the curve, which is why this point implies cost-minimization. This concept can be more easily understood visually by analyzing the following graph:

Figure 2-4



On the above graph, point *P* is therefore the ideal point for this firm to produce at. At this point, the firm produces q_0 units of output at the lowest possible cost which in this case is 175 units of capital and 100 workers. Points *A* and *B* also result in the same level of output q_0 but fall on the isocost line q_1, which makes them costlier than *P* and not the levels of *E* and *K* that the firm will hire at.

To calculate for this tangent point *P*, we set the slopes of the isoquant and the isocost equal to one another:

$$[6]\ \frac{MPe}{MPk} = \frac{w}{r}$$

Therefore, profit-maximization and cost-minimization require the marginal rate of substitution to equal the ratio of input prices. The intuition behind this can be better understood if we rearrange the equation as such:

$$[7]\quad \frac{MPe}{w} = \frac{MPk}{r}$$

What this tells us is, that the last unit of both capital and labor, produce at the cost of employing it. If we recall from the short-run, where the firms hiring decision is confined to how many employees they want to hire as capital is fixed, we equated the wage rate to not just the marginal product of the last employee. But rather the value of MP_e in dollar terms. In the long-run, now that we also consider how much capital to purchase, we will also equate the price of capital to the value of the marginal product of capital. Therefore, long-run profit-maximizing also requires labor and capital to be hired up until this point (up until marginal cost equals marginal benefit):

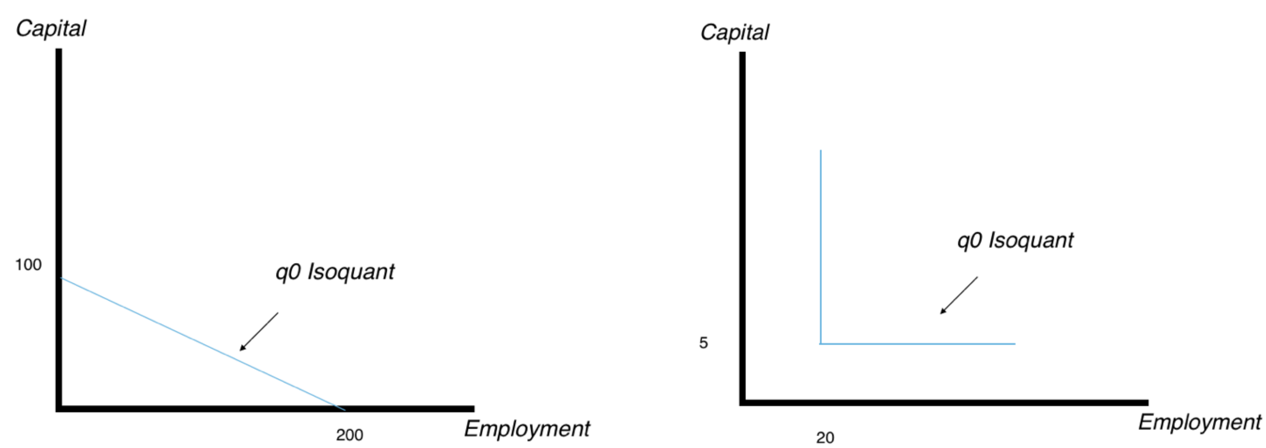
$$[8]\quad w=p^*(MP_e) \text{ and } r=p^*(MP_k)$$

Only after including these profit-maximizing conditions, which also imply cost-minimization, do we have both objectives in place.

2.8 The elasticity of substitution

An essential indicator that can help us determine whether or not automation and artificial intelligence will be able to technologically displace workers, is the *elasticity of substitution*. A firm's elasticity of substitution measures a firm's ability to replace production from a worker with capital and vice versa. For example, if technology can in fact replace and "unemploy" workers, then it must be true that a firm can replace labor with the same or less capital (in terms of cost). Profit-maximizing and cost-minimizing firms will not purchase capital in place of workers if the technology is not as efficient as humans. Again, a better comprehension of this notion can be acquired by looking at the two extreme cases:

Figure 2-5



b) Perfect Substitutes

a) Perfect Compliments

In the first case, where isoquant curve q_0 is linear, workers and capital are perfect substitutes for one another. This means that there is a constant tradeoff between the two inputs. In the above example, for any combination of *E* and *K*, the work of one unit of capital can be replaced by two workers, and vice versa. The optimal solution in this case is to hire only capital <u>or</u> labor; whichever is cheaper. In case *(b)*, where the isoquant curve q_0 represents a right angle, the two inputs are perfect compliments, which means that there is only one recipe to produce this level of output. In this case, the recipe is five units of capital and 20 workers and increasing one input or the other does not result in any increased outputs. In between these two extremes are a number of substitution possibilities that take the form of a regularly curved isoquant that we will work with. The flatter an isoquant is, the more it resembles the linear example and therefore has a higher *substitution effect*. The more curved a curve is, the more similar it is to a right angle and has a lower substitution effect. To measure curvature/substitution we use the following equation:

$$\text{[9] } \textit{Elasticity of Substitution} = \frac{\%\Delta\left(\frac{K}{E}\right)}{\%\Delta\left(\frac{w}{r}\right)}$$

If the isoquant is linear, line in example *(a)*, this equation will equal ∞ and if the curve is right-angled, it will equal 0. Therefore, the higher the Elasticity of Substitution, the less curved the isoquant curve is, and vice versa. We will use this equation to show the effect technological advancements have on the substitution between the two inputs, and specifically, if it will change isoquants and their curvature, resulting in unemployment (Borjas).

2.9 Shifts in labor demand due to changes of elasticity of substitution

The relationship between the elasticity of substitution and labor demand is what is going to drive the analysis we will perform to answer our question. Our next goal will be to show how our improvements in the field of automation and AI will cause capital and employment to become more substitutes of one another, how it changes the elasticity of substitution, and ultimately labor demand/the hiring decision. The following graphic shows what happens when we improve at automating human behavior or are able to do it at a lower cost relative to wages, which would in turn shift the isoquant curve to reflect firms' preference to purchase capital:

Figure 2-6

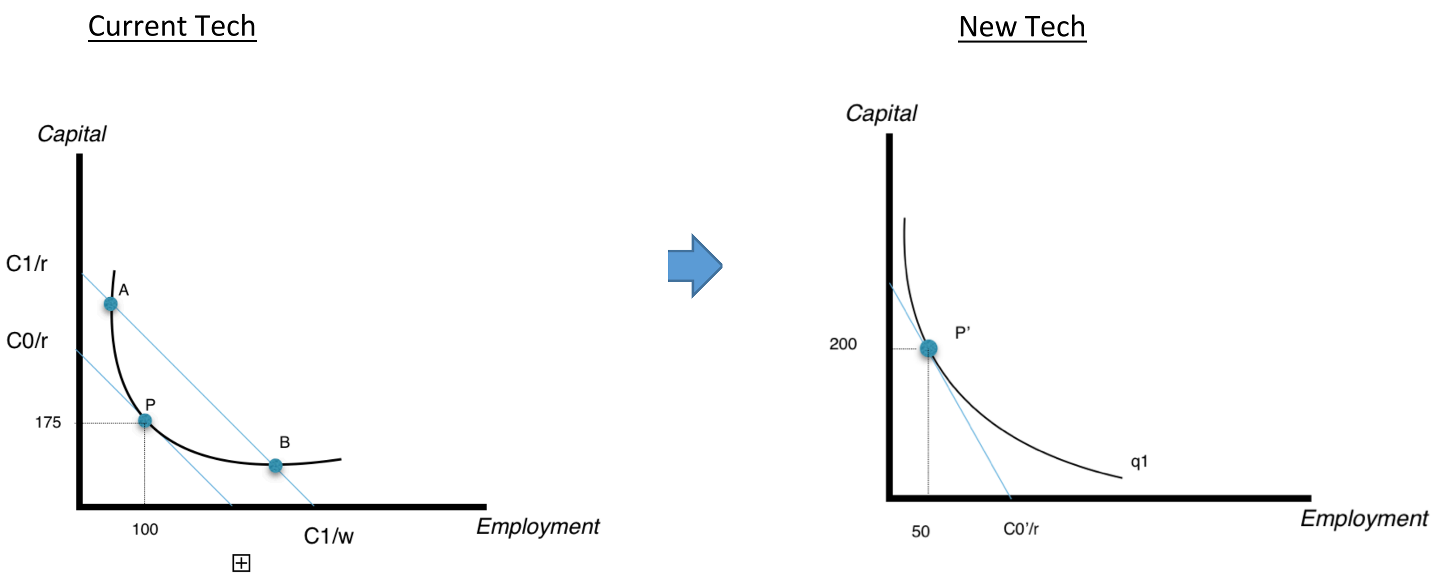


Figure 2-6 represent the outcome of increased cost-efficiency of technology relative to wages. As we will outline later, if this technology does in fact become most cost-efficient than labor, the isocost curve will be steep. We will hypothesize in the next chapter that there is a strong possibility that this is true and we will use a steep isocost curve from here on out. Therefore, the new isoquant curve (q_1) is flattened, and due to the steep slope of the isocost curve (C_0'/r) our new equilibrium combination is *P'*. In this new state, the firm will hire 200 units of capital, and only 50 units of labor, to produce the same output as before. As a result, 50 workers have theoretically lost their jobs and have been replaced by an additional 25 units of new technology. To recall, this occurs because we now have access to new technology that can

better replicate (and ultimately be substituted for) human labor. And we will hypothesize that our isocost curve is steep due to the relative costs of both capital and labor, we arrive at our new levels of employment and capital.

We have now successfully built a theoretical framework and sufficiently outlined and explained the tools we will need to analyze the effects of our development in automation and artificial intelligence on the job market. Chapter 3 will take the theory we just laid out and apply it to the three specific labor segments: high, medium and low-skilled work. We will see that both the starting points and outcomes are very different for all three. Chapter 4 will examine more closely the low-skilled work cohort, as unique outcomes come from this group with severe implications on income inequality. In Chapter 5 we will introduce another approach, which will hopefully confirm and therefore strengthen our hypothesis. And finally, in chapter 6 I will be outlining who the stakeholders are that have the power to prevent this negative effect on the economy and provide recommendations to them.

Chapter 3: Analyzing the effects of Automation on Elasticity of Substitution

The theoretical portion of this thesis has now concluded. It is time to take the theory we derived and apply it to the issue at hand and begin to answer some questions. In the previous chapter, we concluded that the best way to determine if automation can actually cause technological unemployment is to show its effect on the elasticity of substitution between employment and capital. If we recall, the flatter or less curved the isoquant is, the higher degree of substitution is present. Therefore, if technological unemployment is in fact possible, then we will see that the isoquant curve will flatten, which means that workers and capital are becoming more substitutable to one another than before the technology was introduced. Evidently, the substitutability of technology for employees will vary heavily for different kinds of jobs, which is why we will segment employees into three categories (low, medium, and high skilled) in order to show the different outcomes in each one. Each cohort will have its own set of assumptions necessary to perform proper analysis, but there are two assumptions applicable to all three that are very important to remember. The first is that firms in this model act under profit-maximization, meaning that regardless of whether or not we are able to automate their jobs, it also has to be more cost efficient to do so. And second, as we get better and more efficient in the fields of automation and artificial intelligence with time, the costs of purchasing the technology within these fields fall.

3.1 Low-skilled workers

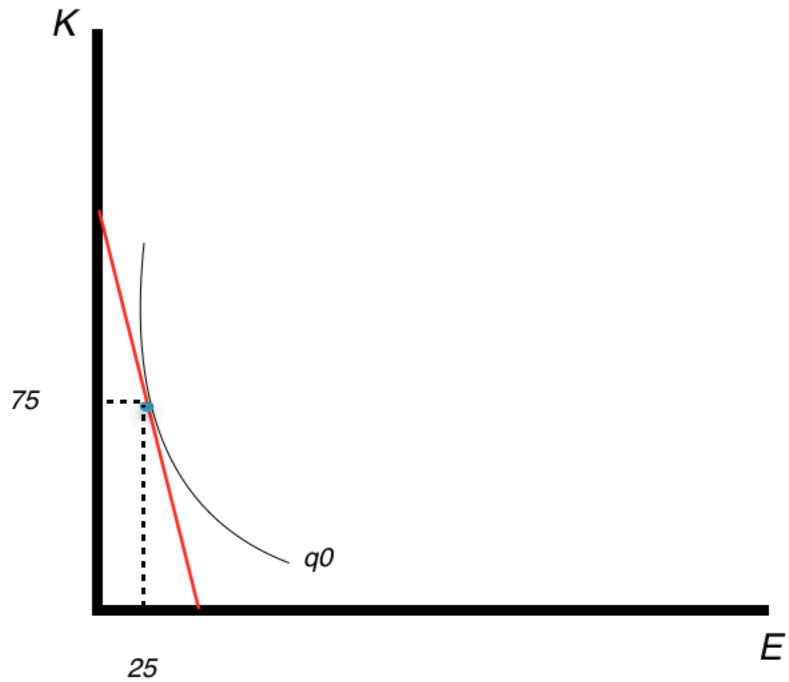
We will begin each segment by outlining the current state of substitution between man and machine within it. As it stands, low-skilled work is the easiest to automate and the numbers reflect it. The heat map in Chapter 1 (figure 1-1) shows what kinds of jobs have the potential to be automated, but if we look at concrete numbers, we can confirm that we are able to, and are replacing low-skilled jobs with technology. To find an example of this, we will look no further than the manufacturing industry; an industry once heavily populated with low-skilled workers, not dominated by automation. This industry provides a sound example of the current state of technological unemployment of low-skilled labor in all industries. Therefore, from our analysis of the manufacturing industry, we will be able to derive the isoquant curve for demand for low-skilled workers in the current state, and use it as a starting point to show the effects our short-run advancements in automation will have on it.

In order to paint the most accurate picture possible of the current state, and therefore arrive at the most accurate future state, we will have to acquire facts and statistics from multiple sources. To begin, it is no secret that from 2000 to 2010, the U.S. has lost 5.6 million manufacturing jobs; an alarming amount (Chui). But is this entirely due to automation? Or are there other factors driving this job reduction in the U.S. like trade? Ball State University, in their 2017 study titled *The Myth and the Reality of Manufacturing in America* concludes that the former is true: most of (almost 90%) of the modern job losses in the manufacturing industry are due to increased productivity per worker – due to automation (Hicks). The effect of our advancements can be portrayed in the following figure by the Financial Times:

Figure 3-1

As you can see, **Figure 3-1** shows that we are producing exponentially more, with a fraction of the employees. Since these numbers include every job and not just low-skilled jobs, we will have to make fact-based assumptions to weed out the current state of low-skilled labor only. Based on **Figure 1-1**, we know that almost all of the automation potential in the manufacturing industry comes from low-skilled jobs. Therefore, we can make a logical conclusion that the reduction in jobs due to automation in the industry are the low-skilled jobs in relation to production in the factory. We now know that currently, automation has displaced most, but not all low-skilled workers. The isoquant curve that exhibits this current state is as follows:

Figure 3-2



Given what we know about the relationship between low-skilled work and automation to this point, the current state of technological unemployment of low-skilled employees is represented by a very flat, but not quite linear, isoquant curve. As well, the isocost curve is very steep due to the location of the tangent point, which is determined by increasing wages and potentially decreasing prices of automation; but we will emphasize this more in a moment. This graph confirms that we are currently experiencing a large amount of technological unemployment in this segment, but there are some low-skilled jobs that aren't currently being automated because it is currently profit-maximizing to hire a mix. Why is this happening if we know that all low-skilled work could theoretically be automated? Since firms chose in a profit-maximizing and cost-minimizing way, we can conclude that the firms who still opt to hire human capital, do so because within this framework it is less costly for them than to buy and install new technology.

Now that we know what the current state is, and how we got there, it is time to talk about the future state. As mentioned, since cost is the most important factor holding firms back from replacing low-skilled labor, it is obvious than that for us to get to our future state (as seen in figure 3-2), the variable that changed the most is in fact the price of the technology. Before we get into the how, let us explain what our future state graph tells us. In the future, automation and human labor will move closer toward being perfect substitutes for one another, which means that any firm can employ entirely humans or entirely automaton to achieve their desired output. If the technology is cheaper, they will fully automate their low-skilled jobs and vice versa for if labor is less expensive. So, which will they choose: all humans or all machines? The answer is simple: firms will choose the cheaper option and that option, is machines. Here's why:

Figure 3-3

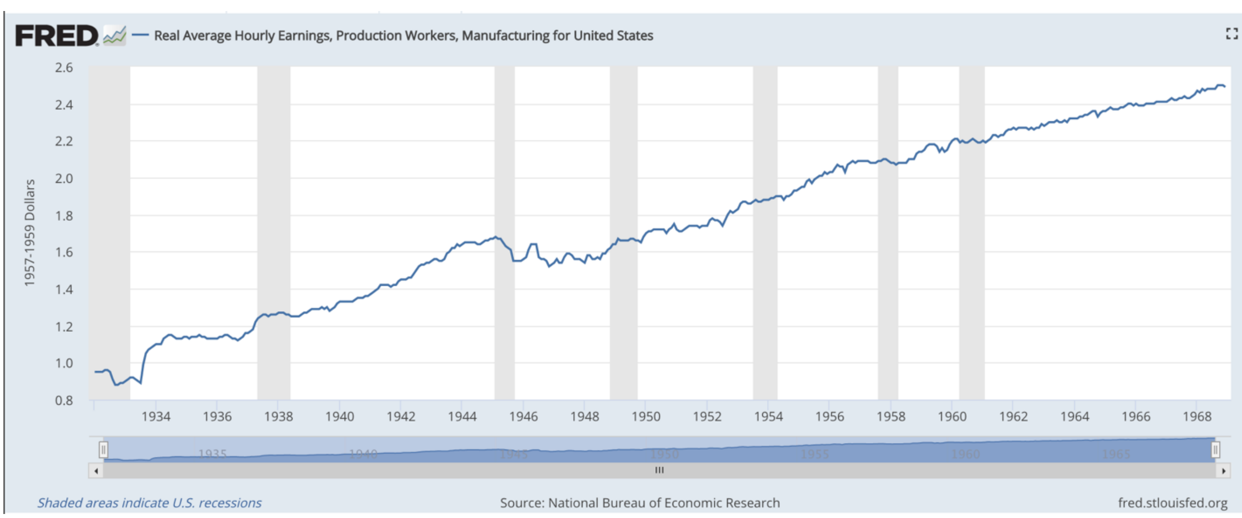
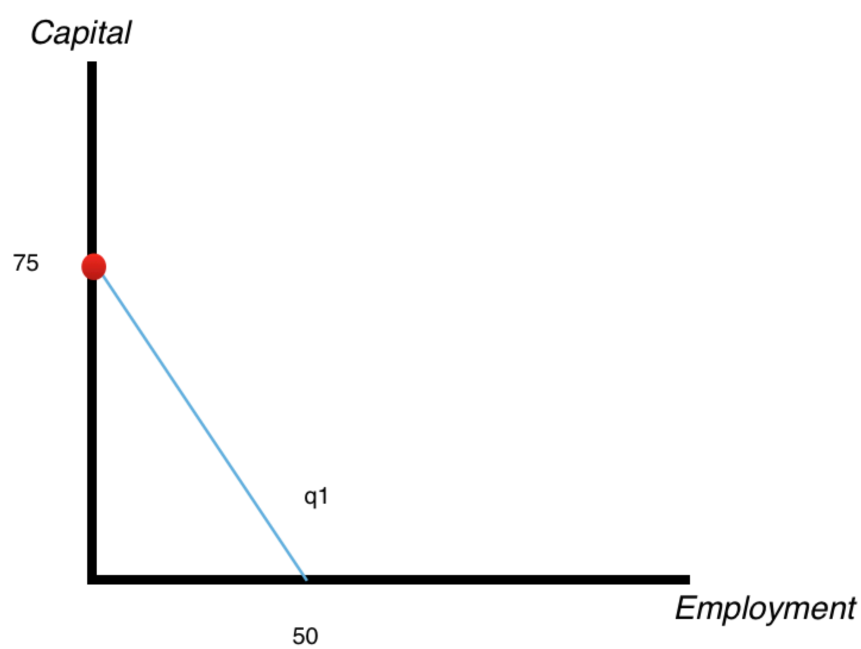


Figure 3-3 shows real hourly wages for low-skilled production workers in the united states from 1932-2017. As you can see, their wages are rising, and hence are becoming more expensive. One may argue that this is because workers are getting more productive and therefore are being paid accordingly. While this may be true, it does not negate our argument as marginal productivity has increased in manufacturing due to the improvement and increase in capital available to workers. This means that while workers are getting paid according to their production and fewer workers are needed; workers are still being substituted for capital in this case.

Nonetheless, it is probable that this trend of increasing real wages, that has existed for nearly 100 years will continue into the future. So, human labor will become more expensive, but is that enough to conclude that technology will be more cost efficient for every firm that labor? Potentially, but in order to solidify our hypothesis, we will also prove that the costs of installing this technology will also go down. This outcome can be supported based on the theory of *Economies of Scale*. When a company experiences economies of scale, as production increases in the long-run, average total cost decreases. If firms who produce automation were to experience economies of scale, then they would be able to produce the technology necessary to replace low-skilled workers at a more affordable rate, which will impact the decision to hire humans or technology. We can suspect that much like many other industries, firms who produce automation will reach this level of production as well (Colander). An important thing to note moving forward is that for all types of skill, we will be guided by the suggestion that since wages are rising and the price of new technology may be falling, the cost of automation will be less than employees in the long-run, which in essence is essential to this approach to the topic at hand. Graphically, this information can support our hypothesis that the isocost curve will be steeper, meaning that capital is more cost-efficient than labor. Therefore, if firms put all of their money into automation, they will get more units of capital than they would have labor if they put all of their money into hiring employees. As we will see, this will drive our analysis and reveal some potential negative economic outcomes deriving from our technological advancement.

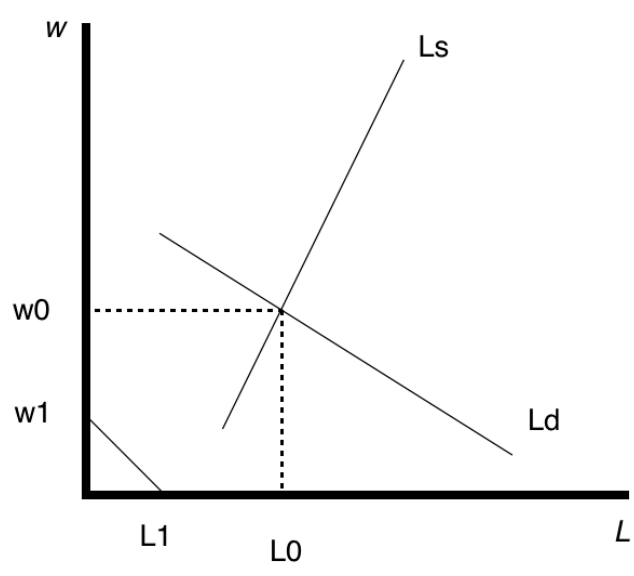
Now we are in a position where we can show what will happen to low-skilled workers in the future state graphically:

Figure 3-4



To recall from **figure 3-2**, the isoquant curve in the current state is very flat with a tangent point that allows the isocost curve to intersect the Y-axis at a greater point than the X-axis, resulting in most of the hiring decision favoring technology rather than low-skilled workers. **Figure 3-4** represents what the tradeoff will look like in the short-run, when labor becomes more expensive and technology becomes cheaper. As you can see, automation and labor have become perfect substitutes for one another, resulting in a corner solution. This means that the optimal solution, or the point at which firms will hire low-skilled labor or technology, will either be entirely one or the other but not a combination of both. As per our hypothesis, firms will hire all automation, and the reason for this can be seen by the effect this has on labor demand:

Figure 3-5

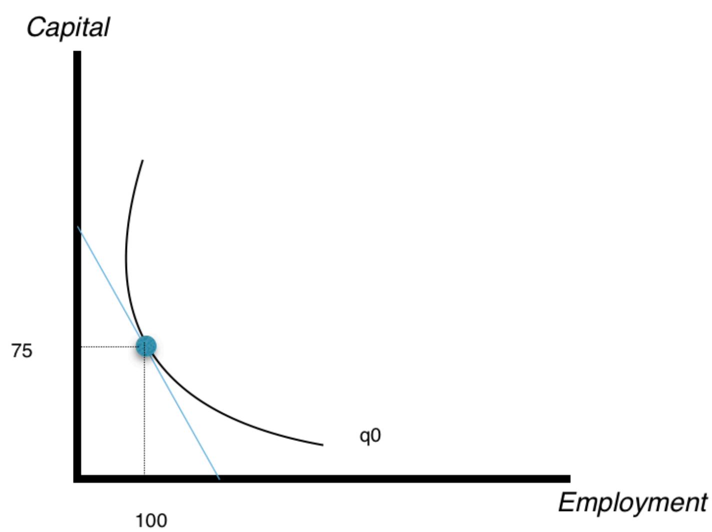


The labor demand graph shows us at how many workers firms are willing to hire at different wages. In both the current and future states, labor supply will be held constant. In the current state, wages and quantity of labor demand are inversely related, as when wages rise, labor demanded falls, and the amount of labor in the market falls as a result. The opposite effect happens when wages fall: labor demanded rises with the amount of workers hired. However, in the future state, where automation and employees are perfect substitutes, the decision to hire employees is not constantly dependent on wages. The future graph shows that firms only hire if wage falls below a certain point, where $w/r < B$**.** At any other wage level, firms will employ only automation and no low-skilled labor. As mentioned, firms will evidently hire some employees if the wage level falls low enough, but they would have to fall to a point that is unrealistic. To get firms to hire any labor, the wage level would have to fall much lower than the current level, which in reality may be very unlikely as the government has laws in place like minimum wage that prevent this. Therefore, we can conclude that in the short-run, firms will replace low-skilled labor with automation, as the profit-maximizing and cost-minimizing conditions suggest that this is the optimal choice.

3.2 Medium-skilled workers

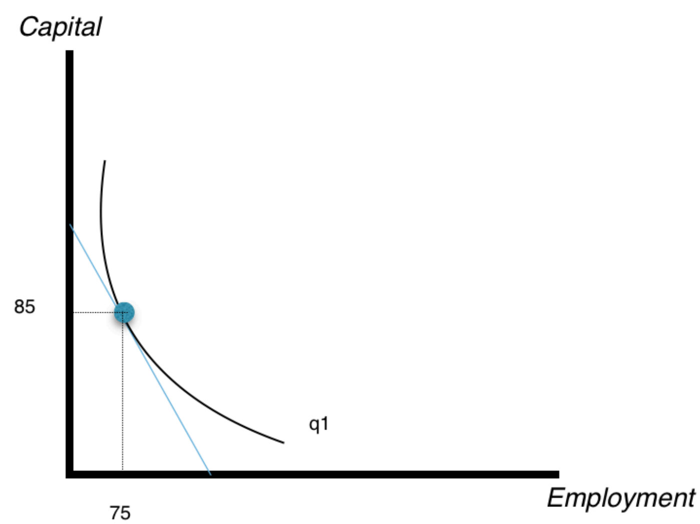
While the bulk of the later chapters of this thesis will focus on low-skilled workers, for the potentially drastic economic problems that will arise in the short-term for that segment of workers, it is still important to show the impact automation will have on medium and high-skilled workers in order to show that the economic burdens may become wide-spread in the long-run. Beginning with medium-skilled workers, we will need to set up a current state that is different than that of low-skilled workers. If we can recall, the level of substitution between technology and low-skilled labor is close to, but not perfect, meaning that the isoquant curve is flat but not linear, with a steep isocost curve, resulting in most but not all low-skilled work being performed by capital. Medium-skilled labor, according to the National Skills Coalition, typically require education beyond high-school for a human to perform and is the largest cohort of workers in the US. Evidently, medium-skilled labor is much harder to automate than low-skilled work, which will be reflected in its curvature. However, according to **Figure 1-1**, we know that there is definitely significant automation potential within this segment, that has and has yet to be captured by technological advancement. Therefore, both our starting and end points will be much different than the low-skilled cohort, but the effect will be very similar. The current state of substitution between capital and employment for medium-skilled workers can be portrayed graphically as follows:

Figure 3-6



As the graph depicts, although much less than low-skilled workers, medium-skilled employees have experienced substitution of their jobs in favor of capital. The isoquant curve is moderately curved, resulting in a trade-off between employees and capital that strongly favors employees. But as we mentioned, there is a lot of automation potential in this space. So, what will happen as we make technological advancements?

Figure 3-7

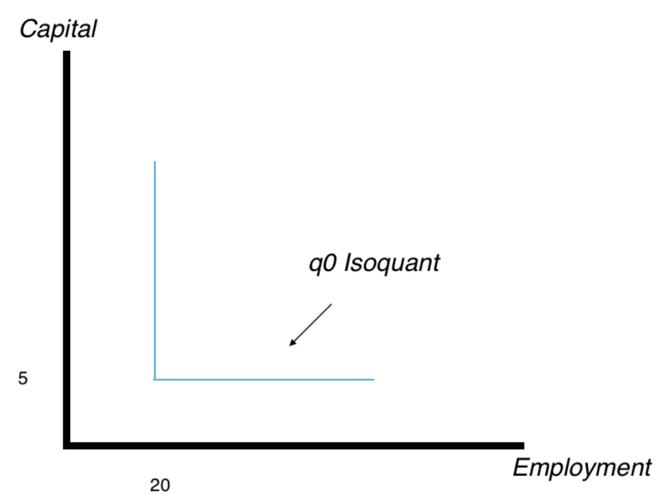


Much like the low-skilled worker cohort, the isoquant curve will flatten due to technological advancements that make automation better at replicating medium-skilled work. Given our steep isocost curve that we derived in the previous part of this chapter, the impending result is that firms that need medium-skilled workers will be able to produce the same amount of output as before (q_0) with fewer workers. Evidently, it is not surprising that automation will have a similar effect on medium-skilled workers, potentially reducing the amount of this type of labor demanded by firms.

3.3 High-skilled workers

It is very likely that some high-skilled work can never be automated. However, as long as there is some automation potential within this group of skilled workers, it is important to highlight it to show just how powerful an impact artificial intelligence can have. The best depiction of the current state of the tradeoff between employment of capital and high-skilled employees is the total opposite of low-skilled workers where there is in fact no substitution at all. In fact, currently, the relationship between artificial intelligence and high-skilled workers is one that is best described as perfect compliments of one another. If we recall from chapter 2, this association can be shown by the following graph:

Figure 3-8



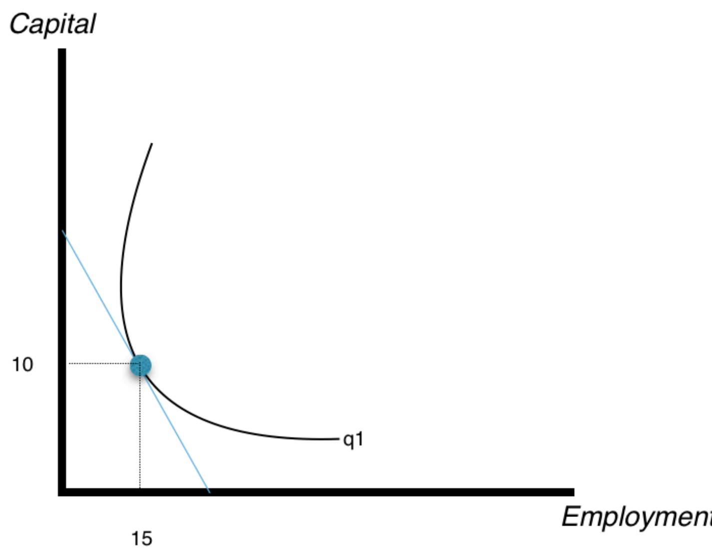
In the above case, the output level associated with isoquant curve q_0 can only be achieved by using 20 units of labor and 5 units of capital. Increasing capital or labor on their own will not change output. To better understand this relationship, we can think of a real-world example of AI and high-skilled labor complimenting each other to work optimally. Artificial intelligence has a huge impact in the world of healthcare. One of its biggest impacts is shortening the wait for patients between taking tests and receiving diagnosis and treatment. An example of this is "The Google Deep Mind Project" which is a program with the goal of using AI to read medical documents within seconds in order to provide patients with a more accurate diagnosis, within a fraction of the time, hopefully leading to more success treating patients with a wide range of health problems. This relationship between doctor and technology is one-to-one (Zaidi). One doctor taking the tests, running the program, inputting the correct data, reviewing the programs diagnosis, etc. and one program crunching the data and providing the diagnosis. In this case, adding another doctor would not make the output any greater, in fact it would probably slow the process down due to the lack of a need for another doctor. And having a second program would evidently be redundant as well, since it would provide the results at the same speed as the first program, and there would have to be double the human input at the beginning of the process, which would again, slow the process down. But this is merely the current state. What if, we were to develop cognitive automation so smart, that it could actually substitute high-skilled labor, and be more than just a compliment to it?

There are many reasons to think that this may be in fact possible. One example that can serve as evidence that it is possible for artificial intelligence to substitute high-skilled labor is in the field of data analytics. Being able to read, understand, and analyze data to make proper decisions based off of it was once a very scarce and skilled type of work, which is why data analysts in certain industries get compensated as such. While data-driven decision making is still very much a scarce and desired skill, it is now possible to automate it, and given the high salaries that these workers make to perform this task, it is not unrealistic to expect firms to choose to hire this automation as a substitute.

But as we know, the technology can't just be cheaper for firms to chose to use it; it also must be just as good, if not better. In this case, despite data analysis being a "high" skill requiring years of education and experience, AI can actually perform it better. In this field, algorithms are said to have a competitive advantage over humans when it comes to pattern detection due to its ability to read massive data sets at an exponentially faster rate than humans can; one of the most important ability to have when properly analyzing data. In practice, we can see this substitution taking place in two industries that rely heavily on high-skilled work: financial services and healthcare (Henry-Nickie). An example in the former is a hedge fund called Man Group, whose CEO Luke Ellis claims that his firm autonomously manages $5.1 billion in assets using algorithms developed by artificial intelligence (Satariano). Another example, this time in the healthcare industry is a startup called Enlitic, a firm who uses artificial intelligence to read CT and MRI scans and radiographs. They claim that their machines can read this data faster and more accurately than four radiologists working at once (Parloff).

Now that we have provided evidence for it being possible for high-skilled work to be substituted by technology (and not just a compliment to it), we can now graphically portray what this future state may look like for high-skilled workers given this knowledge:

Figure 3-9



As we know, the current state isoquant curve is a right angle with no curvature, which tells us that automation and high-skilled labor are compliments for one another. However, as we advance and become better at replicating this work, we will see that I the future state there will be some curvature to the isoquant curve for high-skilled work. This means that eventually, firms will opt to purchase artificial intelligence in place of high-skilled workers, adding to the mass economic outcome of our progression in computer science.

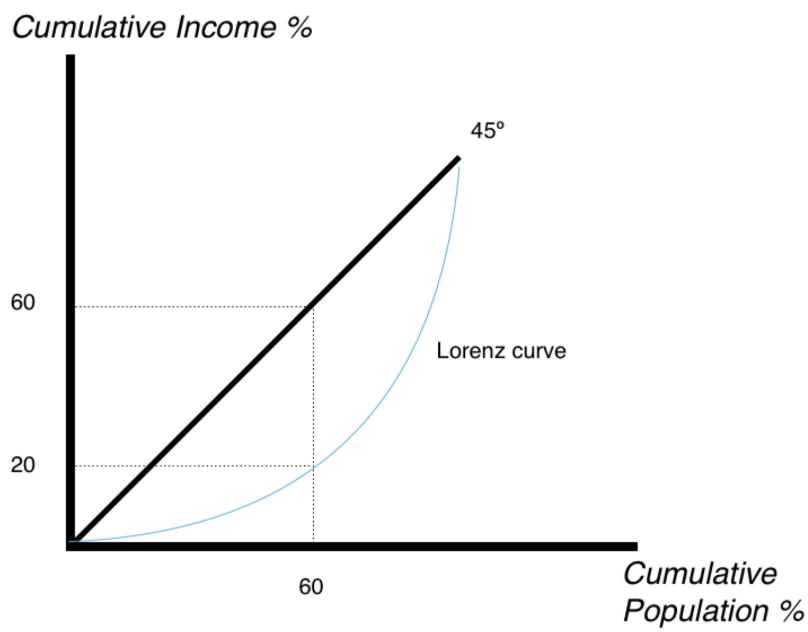
Chapter 4: The Short-Run Problem of Income Inequality

As we have portrayed, all types of labor will be affected by AI. However, the rest of this thesis will primarily focus on the low-skilled worker segment. The reason being is that it is clear that this segment will drive our inequality analysis as the possibility of automation being a perfect substitute of this type of work could have the most severe and immediate impact on the economy. If the results outlined by our framework are true for low-skilled workers, then one of the most important issues to look at will be income inequality. If we recall from our first chapter, low-skilled workers earn the lowest wages. If they are at risk of losing their jobs to technology or having their wages reduced, either way, income inequality will worsen in the U.S. as the lowest end of the distribution would be poorer, and even more profits would be directed at the richest. This chapter will outline this problem from two perspectives from two different schools of thought, to attempt to show that our technological advancements may lead to an increase in income inequality in the U.S.

4.1 Outlining the income inequality problem

Income inequality in any given country can be best visualized by a Lorenz Curve:

Figure 4-1

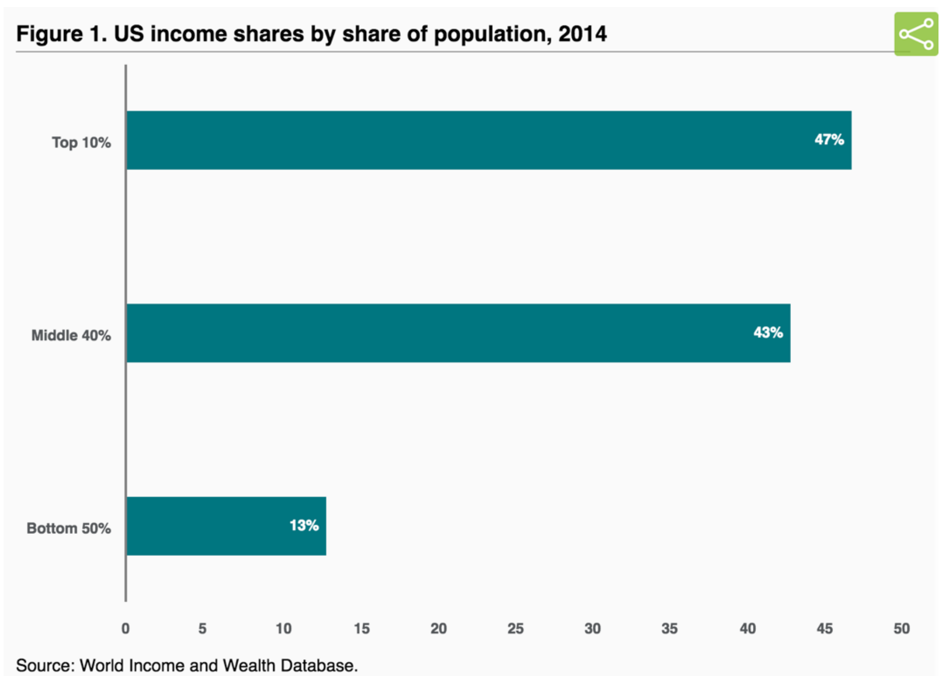


The 45^{o} degree line that dissects the X-Y plane is called the *Line of Perfect Equality* and its name is accurate for what it represents. If a country's Lorenz curve is represented by this line, then they have perfect income equality within it. In the case of **Figure 4-1**, 60% of the cumulative population earns 60% of the income. This would be true for any percent of the population as they would earn an equal share of the income in the country. However, most country's do not experience perfect income equality, and their Lorenz curve looks more similar to the blue one above. In this case, 60% of the population only earns 20% of the income, and the other 40% earns 80%. The lower a country's Lorenz curve falls below the 45^{o}, the more income inequality exists within it.

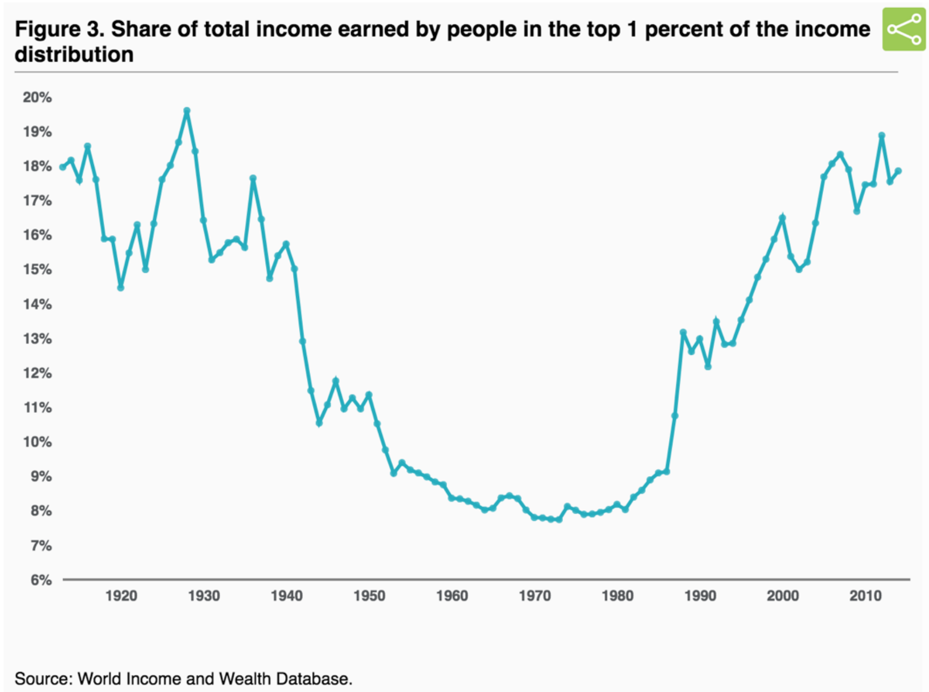
In a market-based, capitalistic economic system like the U.S. has adopted, it would be unrealistic to expect there to be perfect income equality. However, the gap between the richest and the poorest has been spreading and spreading in this country, and there is no evidence of that stopping any time soon. It has reached a point where the gap is so big that it not merely a product of the economic system in place; it is a serious problem and the numbers do not lie. If we look at US income shares by percent of the population, the results are as follows:

Figure 4-2

a)



b)



If we recall, in a country with perfect income equality, 1% of the population earns 1% of the income, 10% earns 10% and so on. However, in the United States, the top 1% receives around 20% of the total income and the top 10% is earning about half of the total income.

It is evident that the US is suffering from high levels of income inequality. While it may be trivial to some why having severe income inequality in a country is bad, it is still important to talk about why it is so harmful to an economy. First and foremost, high levels of income inequality prevent a large portion of the country from being exposed to certain opportunities and outcomes. This means that some people, given their ethnicity, location of birth, family background etc. will not be given the same chance to succeed as other people simply based on their circumstance and not anything else. While this is obviously not very fair (or "American" for that matter), the fact that a larger and larger percentage of the country is being restricted from achieving success, there are also macroeconomic effects that come as a result. For example, a country with high-income inequality tends to also experience a slowing down of their growth drivers. The reason being that lower-income household's inability to accumulate human or physical capital and stay healthy which leads to underinvestment in these locations in areas such as education. When low-income households are deprived of the opportunity to a good education they are less likely to go to college, which lowers labor productivity. Therefore, as the amount of low-income households rises with inequality, the more impact this lack on productivity has on the country as a whole. As well, inequality can hinder growth by reducing investment as it fuels political, financial and economic instability (Kochhar).

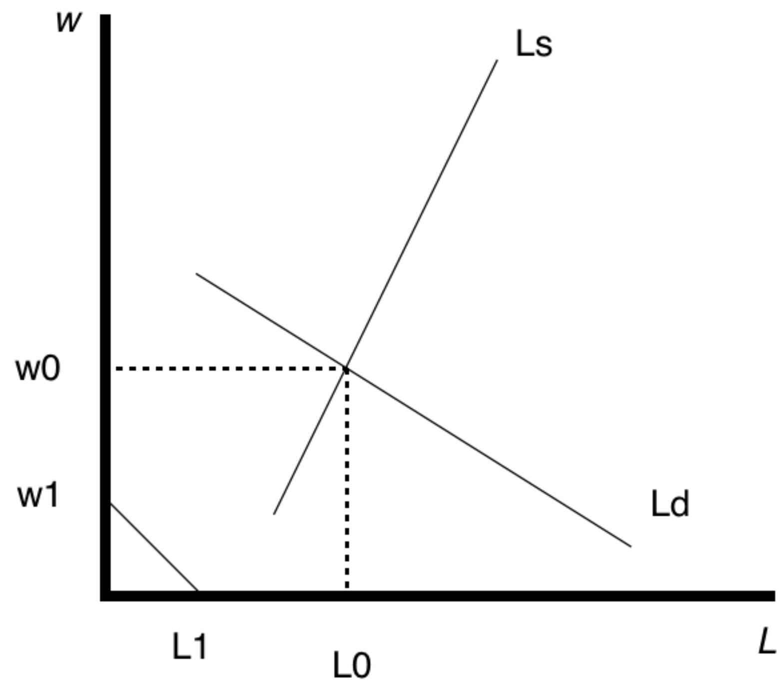
4.2 Automation's role in income inequality

We are now aware of what income inequality is, that the United States is currently experiencing alarming levels of it and that we hypothesized that our analysis of how automation and AI will affect elasticity of substitution may cause it to get worse. The next part of Chapter 4 will try to use economic theory to explain why our technological advancements and their effect on firm's decisions to hire more automation than employees will lead to increased income inequality. To reiterate, we will focus on the low-skilled worker segment because, as outlined in chapter 3, they will be the most prone to substitution by AI. As well, low-skilled workers make up the low-income households that we need to make better off to fix income inequality. However, what we have hypothesized to find is that these low-skilled and low-income workers are going to be made worse off by this technology, which will ultimately worsen income inequality in the US. In order to hopefully provide stronger evidence for this conclusion, this chapter will introduce two different approaches to the relationship between advancements in automation and increased income inequality.

4.3 A neoclassical approach

We will remain consistent in our theoretical framework to begin with, by looking at this income inequality issue with a neoclassical framework. To recall, the future state of elasticity of substitution between automation and low-skilled workers leaves us at a corner solution; meaning we will either hire all automation or only high-skilled workers, depending on which is cheaper. We hypothesized that eventually, it is probable that this technology will become cheaper than paying employees at the real wage. Therefore, firms may exclusively hire automation to perform low-skilled work in the short-run. The impending result of this effect on elasticity on the neoclassical labor demand graph will be as follows:

Figure 4-3



In chapter 3 we used this graph to explain the condition for which firms will hire all capital and no low-skilled labor. If we recall, firms chose to do this insofar as w/r > B. This same graph can be used to portray the neoclassical outlook on how automation may worsen income inequality. Given the graph above, there are two possible scenarios: 1) The future state wage rate remains at its current level (or rises), and firms have 0 labor demand for low-skilled workers as they would much prefer to install automation for cheaper. Or 2) the wage rate drops significantly in the future, making it profit maximizing to hire some, but less, low-skilled workers. Although it is probable that scenario 2) will never happen considering real wages consistently rise and it is unlikely that the government would slash the minimum wage, which is the rate that most of low-skilled workers earn. Regardless, in either scenario, if they come true, low-skilled workers are made much worse off, worsening income inequality. In the first outcome, low-skilled workers are completely unemployed, turning their already low incomes into nothing. In the second, they are employed, but their low incomes become even lower. As one can see, in either scenario, according to the neoclassical framework, the already significant problem of income inequality in the U.S. will worsen if our hypotheses come true.

Chapter 5: An Alternative Approach – The Sraffa Model

As previously mentioned, we will now bring in a non-neoclassical approach to income inequality in order to strengthen and hopefully confirm our hypothesis. The model we will use was created by Piero Sraffa, an Italian economist who provided a unique outlook on income inequality in 1960, which happens to be extremely useful when analyzing the problem at hand (HET). This framework differs from our neoclassical one in a few ways. Firstly, in the neoclassical model profit is determined by the market; specifically, consumer demand. In Sraffa's model, profits are determined by the worker-capitalist conflict. It focusses on this conflict by introducing a variable labeled "*r*" which represents how much profits a capitalist or owner keeps for himself. By focusing on the worker-capitalist conflict, we obtain different insight into the issue at hand; as we will see moving forward. He begins by conveniently assuming a two-sector economy consisting of 2 industries that produces two goods. Good one or "i" is a natural resource, wheat, and good two or "j" is iron which represents capital. To produce either good, we will need some combination of both goods and some labor. We will call variations of these combinations as "recipes". The following is an example of what a recipe in this model may look like:

Figure 5-1

a(11) = 0.3	a(12) = 0.2
a(21) = 0.2	a(22) = 0.4
L(1) = 0.1	L(2) = 0.2

The left column represents the recipe for producing one unit of good 1. Similarly, the right column represents the recipe for producing a unit of good 2. For example, the left-hand recipe tells us that in order to produce one unit of good 1, we would need 0.3 units of good 1, 0.2 units of good 2, and 0.1 units of labor. We will continue to assume that firms' actions will be guided by profit-maximization (Borjas: 2013). Meaning, if given the choice to hire more labor or capital to produce the same number of units of either good, they will choose to hire the combination or recipe granting them the most profit. We will use the following equation to measure profit, which we will then use to determine firms' hiring decisions and ultimately its effect on income inequality:

$$Profits = TR-TC$$

In the above equation, TR stands for total revenue and can be calculated by multiplying the total quantity of the goods produced by the price of the good. TC (Total costs), are the costs of production and can be calculated by multiplying the costs of both inputs by the number of inputs required to produce the good, multiplying the wage rate by the required units of labor, and finding the sum of the two. We can refer to the cost of an input as either "P(1)" or "P(2)" and the wage rate as "w". Finally, an important metric we must add that will help with determining the effect of technological advancements on income inequality is the share of income the capitalist receives from profits, rather than workers. The percent share capitalists take can be labeled as r(i) and is the same in both industries.

A conclusion Sraffa comes to is that as the percent of profits that capitalists take increases, wages decrease. Proving this notion will be important for our analysis of how technological changes affect income inequality. An assumption Sraffa makes, which is essential for our following steps, is non-labor cost is paid in advance of production but labor is paid after. This means the only costs per-unit the capitalist faces is the non-labor costs or $[p(i)*a(ii)+p(j)*a(ji)]$. Therefore, profit per unit can be calculated as $1=r[p(i)*a(ii)+p(j)*a(ji)]$. For our upcoming analysis, we will now need to rewrite the accounting identity *Revenue = Costs + Profits* on a per unit bases (which will become more apparent why as we move forward) for both industries; which we are now equipped to do:

<u>Industry 1:</u> $[p(1)a(11) + p(2)a(21)] + wL(1) + r[p(1)a(11) + p(2)a(21)] = p(1)$

Cost Per Unit — *Profit Per Unit* — *Revenue Per Unit/Price*

For ease of use, we can rewrite as for both industry 1 and industry 2 respectively:

(1) $(1+r)\ [p(1)a(11) + p(2)a(21)] + wL(1) = p(1)$

(2) $(1+r)\ [p(1)a(12) + p(2)a(22)] + wL(2) = p(2)$

Since there are 4 unknown variables in the above equations, we will need to make the appropriate assumptions to narrow it down to 2. We will assume the price of good 2, p(2), is equal to 1. This eliminates a variable and does not hurt our analysis because we are still able to compare the price of good 1, relative to good 2; the exact amounts aren’t necessarily essential.

Also, we will set r=0% in our first calculation and 20% in our second. This removes the final extra variable and allows us to prove Sraffa's hypothesis that wages decrease as the profit rate increases. If we plug in the values from the example recipe we used (**Figure 5-1)** previously, and the assumptions we just made, starting with r=0% (capitalists keep 0% of profits) we get:

(1) *(1+0)[0.3p(1) + 0.2(1)] + 0.1w = p(1);*

(2) *(1+0)[0.2p(1) + 0.4(1)] + 0.2w = 1;*

0.1w = 0.7p(1) – 0.2;

0.2w = 0.6 – 0.2p(1);

7p(1) – 2 = w = 3 – p(1); 8p(1) = 5;

w = 3 – p(1) = 3 – 0.625;

0.3p(1) + 0.2 + 0.1w = p(1)

0.2p(1) + 0.4 + 0.2w = 1

w = 7p(1) – 2

w = 3 – p(1)

p(1) = 5/8; p(1) = 0.625

w = 2.375.

If we do the same analysis with r=20%, the corresponding values are p(1)=0.658 and w=1.811. It is clear that an increase in the rate of profit is kept by capitalists, wages decrease and prices increase. This result is not only important for the analysis we are about to do to show the relationship between technological advancements and increased income inequality, but it will also give us key insight to make recommendations on how to stop it from worsening, which we will talk more about in Chapter 6.

We have now completed enough analysis to begin answering our question: will technological advancements cause firms to employ less low-skilled labor, and replace them with technology and/or pay them at a lower rate, worsening income inequality. In order to do this, we will have to use two different recipes for production, one with our current state of technology, and another representing what would happen if we continue to improve at replicating labor with capital. We will assume all work in the industries is low skilled, so we can specifically see the effect on the group of workers on the lowest end of the income distribution. Firms will have the following recipes available to them in order to produce both goods:

Recipe 1

a(11)=0.3 *a(12)=0.2*

a(21)=0.2 *a(22)=0.4*

L(1)=0.1 *L(2)=0.2*

Recipe 2

a'(11)=0.3 *a'(12)=0.2*

a'(21)=0.3 *a'(22)=0.4*

L'(1)=0.05 *L'(2)-0.2*

In the above recipes, recipe 1 represents our current state of technology, and recipe 2 represents an alternative option if the firm should choose to adopt new technology. In our case, we will assume this new technology is automation. The intuition behind the differences between recipe 1 and recipe 2 is as follows: since automation has improved, firms are able to produce one unit of good 1 with half the amount of labor as before. However, the firm won't choose the new recipe over the old one, unless the extra amount of money invested in the new technology is less than the amount saved from hiring less labor. To calculate the extra money spent on capital we multiply the difference between the amounts of good 2 necessary to produce good 1 (a[21]-a'[21]) by the price of good 2. To find the savings on labor, we will multiply the difference between the amount of labor necessary to produce a unit of good 1 by the wage. Using those formulas, we get; first assuming r=0% and using w=0.2375 from our previous calculations:

*Extra spent on capital = (0.3-0.2)*1=0.1*

*Amount saved on labor = (0.1-0.05)*2.375=0.119*

Since the amount saved on labor costs exceeds the cost of adopting this new technology, firms will choose to replace workers with the new tech. However, let’s see what happens when we increase the rate of profit to r=20% and as a result w=1.811:

*Extra spent on capital = (0.3-0.2)*1=0.1*

*Amount saved on labor = (0.1-0.05)*1.811=0.091*

Since the amount saved on labor costs is less than the actual investment to purchase automation to replace workers, the firm will choose not to adopt the new technology and remain with recipe 1. Although firms will decide not to install the automation in this case, it is essential to note that wages had to decrease in order for them to make that decision (Hahnel).

It is clear that much like our neoclassical analysis, the Sraffian model would confirm our hypothesis about artificial intelligence and increased income inequality. In the two examples we looked at, one where firms adopt capital that replaces workers and the other in which they choose not to, both resulted in an outcome that worsened income inequality. In the first, we explained what would happen if this new technology becomes more cost-efficient than hiring workers. Since we have acknowledged that we are more than capable of replicating almost all low-skilled labor with automation and assume firms will be guided by profit-maximization, this scenario shows what would happen if the only barrier (cost) this technology is currently facing when it comes to displacing a significant amount of low-skilled jobs is removed. Once the price of purchasing automation to produce goods or services is realized to be less over time than hiring workers, firms will eventually begin the process of switching to a more capital-intensive production process. In the second example, while low-skilled workers keep their jobs, they are paid at a lower rate than their already low income. As previously mentioned, this will inherently worsen income inequality because low-skilled workers, who make the least amount of income, will make even less income (if any) due to the even greater surplus of potential laborers for the shrinking amount of vacancies available. We can conclude that Sraffa's model would also confirm our prediction that advancements in AI may lead to worse income inequality in the US.

Chapter 6: Policy Recommendations and Conclusions

While this paper to this point has outlined the potential negative economic outcomes of a prominent issue, it would not be complete, nor right, to fail to provide recommendations based on the analysis we have done to try and stop them from happening. To this point, we have determined that it is most likely that automation and artificial intelligence will impact low-skilled workers the most, and most immediately. We have done this by using a neoclassical approach to the labor market and elasticity of substitution between capital and employment. What we found is that based on data outlining the present substitution levels, and predictions about the future, that the tradeoff between automation and low-skilled workers in the future can be best described as perfect substitutes. The framework that we chose tells us that in this scenario, where technology and low-skilled workers are perfect substitutes for one another, we arrive at a corner solution. This means that firms will hire only technology or only low-skilled workers; whichever is more cost-efficient. We then provided reasons for why it is possible for automation to be more cost-efficient than paying the wages of low-skilled workers, coming to a hypothesis that firms will replace their remaining low-skilled workers with automation.

We then explained that although this may be an unemployment problem, we would be better off treating this as an income inequality issue. This is the case for 2 reasons: 1) It is unclear whether or not our advancements in automation will lead to an increased level of unemployment as these progressions may add a job for every job it takes away and 2) even if it does, income inequality will increase, as low-skilled and low-pay workers will be at harm. Next, we summarized how these people will be at harm by deriving the outcomes based on two different approached to income inequality: a neoclassical and a Sraffian model. Both frameworks, although with differing methodology, came to similar conclusions. If our predictions about the relationship between AI and low-skilled workers are true, they will have one of two things happen to them. They could either be replaced by technology as firms opt to hire AI in their place, or firms will decide not to but a wage cut is necessary for them to chose this route. Either way, low-skilled workers are made worse off, increasing income inequality.

6.1 Policy Recommendations

Our next and final objective of this thesis is to provide policy recommendations on how to offset these outcomes or stop them all together. There are a few ways the government can prevent technology from increasing unemployment, but we will mainly focus on two: taxation and redistribution. As we will see, taxation will be a short-term fix. However, if we really want to stop automation from increasing income inequality, proper redistribution of the tax revenue will be essential. Beginning with taxation, in order to reduce increased income inequality from substitution of low-skilled labor with technology, the government will need to implement new tax laws that disincentivize firms from making this substitution. As we know, according to our framework, firms will always act in profit-maximizing ways, regardless of the outcome. Therefore, our preventative policy recommendations will have to target variables that make the profit-maximizing decision not to replace low-skilled workers or lower their wages in favor of technology. There are two ways this can be done. Our recommended policies can either make capital more expensive or make low-skilled labor less expensive. We will focus on using taxation to accomplish the former because reducing wages simply cannot be the answer, as making labor less expensive would make income inequality worse.

But how can we use taxation to make production via automation more expensive, disincentivizing firms to substitute it in place of low-skilled workers? If a targeted new tax is imposed on firms, we may be able to prevent firms from doing so. For example, firms could be taxed for having too high of an output to employee ratio. If a firm produces a high enough level of output, while hiring few low-skilled workers, all revenue generated after this point should be taxed at a higher rate. This would disincentivize firms from automating their low-skilled work to a point that their ratio of revenue to workers is too high. This also makes choosing to install automation less cost-efficient, making it more profitable to keep low-skilled workers employed, which would prevent worsening income inequality. Theoretically, this change would flatten the isocost curve associated with our framework, reducing the substitution of employment for capital.

This potential fix is merely a short-term solution, as we will continue to technologically advance and this problem of income inequality will keep reoccurring. However, what it will do is give us the time, and potentially the capital (via the tax revenue that it generates) to provide a long-term and hopefully permanent fix. There may be some opportunities to redistribute the revenue generated from the new tax, in order to fund longer-term solutions to growing income inequality. Firstly, just as it is essential to be familiar with things like a computer, a telephone, etc. in today's day and age. Tomorrow's baseline of understanding of technology won't be as basic. It may be necessary to have a general understanding of computer science to contribute to tomorrow's society. Some of this money should be redistributed to provide courses embedded in middle and high school systems nationwide, which would prepare the next generation sufficiently for this next wave of technological advancement. Another priority that if focused on would help defend against income inequality caused by technological advancement is a job guarantee program. Economists who advocate for job guarantee, suggest that a program that grants every American a job with a solid wage and benefits can potentially be the best and fastest fix to income inequality for a few reasons. First of all, if every American has a job, inequality is immediately made better, as all of those unemployed are now making a stable wage. Therefore, those at the very bottom of the income distribution, are now made better off, reducing income inequality overall. However, the benefits do not stop there. Theorists in favor of job guarantee also claim that wages will increase, making wage earners better off, which will also reduce income inequality. When this program is paired with a taxation on too high of an output to employee ratio, there may be some potential for a long-term solution to income inequality caused by technological advancements.

6.2 Missing pieces and potential next steps

This very complex solution, although extremely simplified, comes with many considerations that need to be taken into account for it to work. For example, proper policies would have to accompany this new tax to make sure that firms simply don't move their production to a different country that allows for mass automation, making income inequality even worse as all jobs, low, medium, and high, will all be gone. As well, there is potential to examine what would happen to aggregate demand if mass automation occurs. It would be interesting to study the effects of our hypothesis that all low-skilled labor may be replaced by automation on overall economic health. The premise being that if all low-skilled laborers are unemployed, will firms have a big enough market to sell too? What if capitalists hold too much of the production power and profits that they simply cannot sell their goods or services to anyone, because their market was stripped of all their disposable income due to automation? One final area of this issue that would be interesting to study is the role of managers (who are considered medium-skilled) in this new work environment. Management plays a very vital role in a firm's success, as they use their strong interpersonal skills to synergize employees with upper management and owners and makes sure things run smoothly. However, what happens if employees are replaced by technology? Would managers become irrelevant? What other skills would they have to possess other than interpersonal skills to perform their job?

6.3 Conclusion

While this thesis serves as a theoretical contribution to the concept of "robots taking our jobs", there is undoubtedly a lot of tangible lessons that have been uncovered. First and foremost, this is a real issue. The conflict between technology and employment is real and economically significant to study as done in this thesis. Additionally, if anything at all, we have provided a framework that makes the issue much easier to understand. One of our first goals was to make sense of the concept of robots taking jobs and I believe we have successfully done so. By segmenting workers into 3 segments (low, medium, and high-skilled) and worked through a neoclassical framework, we were able to come to logical conclusions on what the outcomes of our technological progress may be. Considering that we began by (although half-jokingly) stating that we were all doomed, it is safe to say that after reading this thesis one can at least make a rational decision for themselves whether or not he thinks my hypotheses are correct or make his own predictions by critiquing the claims I have made. Nonetheless, it will be interesting to see how the issue of technological unemployment will unfold, and hopefully be monitored as we enter this new wave of progression, so that we can be ready for the potential threats that come with it.

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