The Future of Technology Bargaining in the Information Age

by

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Abstract

This thesis was motivated by the advent of digital technologies and their effects on workers. Using technology as a substitute for labor is a common industrial practice and the effects of substitution (though not the decision to substitute) will continue to dominate collective bargaining in the information age.

More relevant than substitution is the effect that digital technologies are having on the production process itself. It is becoming 'taskified' and 'digitized.' Decomposed into smaller, well-defined tasks that are also digitally compatible with each other, the entire production process is becoming easier to direct, control, and monitor. Each new task presents management a new lever of power in two forms – the decision to substitute and the ability to monitor.

While substitution of technology for labor remains an issue, the complementarity of labor and technology contributions in the production process is becoming more important; apportioning value created to a factor in the production process is especially complicated and subjective with large numbers of complementary tasks.

The need for labor education is amplified by these factors and argues for a renewed interest in technology bargaining. A policy examination from various labor-related organizations and informant discussions suggest that labor recognizes this and is responding accordingly. Bargaining agreements have data and technology clauses, 'digital union representatives' are being hired, and education on digital technologies is being prioritized.

Keywords: Complementarity, Decision bargaining, Effects bargaining, Industrial relations, Labor education, Labor substitution, Power, Production process, Taskification, Technology bargaining, Worker monitoring

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Contents

Glossary

binary economics binary economics can be distinguished from conventional economic theory through three fundamental and related assumptions:

1. Labor and capital are *independently productive*.
2. Technological innovation makes capital much more productive than labor.
3. Capital has a strong, positive *distributive* relationship to growth, such that the more broadly capital is acquired, the more its productiveness increases output.

(N. A. Ashford and Hall 2011). 9, 23, 41

codetermination a firm's shareholders and workers share control over major strategic decisions, and managers and workers share control over day-to-day decision-making (Jager, Noy, and Schoefer 2022). Whereas technology bargaining is a legal construct, codetermination a power construct. 18, 60

economic rent the amount paid to a factor (e.g., labor or technology) that exceeds the minimum payment necessary to keep that factor in use or employed (Oxford English Dictionary 2022a). 44

industrial revolution there is no definitive or widely accepted definition of an industrial revolution, so this paper generally follows the eras defined in *The Fourth Industrial Revolution* (Schwab 2017). The first industrial revolution occurred from roughly 1760 to 1840 and is defined by the steam engine and mechanization. The second industrial revolution spanned from the late 1800s to the early 1900s and is defined by electrification and the assembly line. The third industrial revolution begins in the 1960s and is defined by semiconductors, computers, and the internet. This is often referred to as the 'Information Age.' The fourth industrial revolution, beginning roughly at the turn of the millennium, is defined by Schwab as 'more sophisticated and integrated' digital technologies. This thesis does not distinguish the Information Age from the fourth industrial revolution. 9, 27, 28, 82, 85

information age see industrial revolution. 18, 19, 20, 27, 46, 61, 73

labor share is the fraction of economic output that accrues to workers as compensation in exchange for their labor, $\frac{total\ compensation}{value-added\ output}$. Total compensation includes wages and benefits and value-added output is defined as 'gross output minus intermediate inputs, less the output of sectors in which output data are derived from input data' (Giandrea and Sprague 2017). 16, 17, 52

productiveness can be understood retrospectively to mean work done by each factor, and prospectively to mean productive capacity (Robert Ashford via N. A. Ashford and Hall 2011). See also binary economics and productivity. 8, 9, 93

productivity is the ratio of the total output of all factors of production divided by a single factor of input (e.g., labor, technology) or all (total) factors of input. Total output can be gross output or value-added output. If the denominator is a single factor of production, it is often specified (e.g., labor productivity). See also binary economics, productiveness, and total factor productivity. 9, 16, 22, 54

total factor productivity is the ratio of aggregate outputs to aggregate inputs. Total factor productivity *growth* is the component of overall output growth that cannot be explained by accounting for changes in observable labor and capital inputs. It has been called a 'measure of our ignorance' (Abramovitz via Brynjolfsson, Mitchell, and Rock 2018). 9, 22, 85

Acronyms

AEI American Enterprise Institute. 75

AFL-CIO The American Federation of Labor and Congress of Industrial Organizations. 66, 69, 76, 79

AI Artificial Intelligence. 16, 28, 38, 47, 82

API Application Program Interface. 29

CKPU Coalition of Kaiser Permanente Unions. 92

CPI Consumer Price Index. 18

DBMS Database Management System. 29

DOL Department of Labor. 67, 76, 80

DOT Dictionary of Occupational Titles. 33

DRY Don't Repeat Yourself. 32

EPI Economic Policy Institute. 57, 75

ETUC European Trade Union Confederation. 76

ETUI European Trade Union Institute. 76

GM General Motors. 91, 92

GPT General Purpose Technology. 28, 81, 82, 85

ICT Information & Communication Technology. 83, 85

ILO International Labor Organisation. 60, 76

ILR School of Industrial and Labor Relations. 75

IoT Internet of Things. 87

ISP Interface Segregation Principle. 32

IT Information Technology. 65

IWER Institute for Work and Employment Research. 69, 75, 79

KP Kaiser Permanente. 92

LMP Labor Management Partnership. 91, 92

MIT Massachusetts Institute of Technology. 27, 69, 75, 79

ML Machine Learning. 16, 28, 38, 82

NBER National Bureau of Economic Research. 76

NLRA National Labor Relations Act. 24, 43, 59, 60, 65, 74

NLRB National Labor Relations Board. 25, 59, 60, 67

O*NET Occupational Information Network. 33

OED Oxford English Dictionary. 15, 58, 93

OS Operating System. 29

OSTP Office of Science and Technology Policy. 67

SaaS Software as a Service. 43

SDK Software Development Kit. 29

SRP Single Responsibility Principle. 29, 32

TCP/IP Transport Control Protocol / Internet Protocol. 29

TFP Total Factor Productivity. *Glossary:* total factor productivity, 85

UAW United Auto Workers. 76, 91, 92

UBT Unit Based Team. 92

UC University of California. 67, 75, 79

UE United Electric. 77

UN United Nations. 76

UPS United Parcel Service. 65

US United States. 18, 24, 33, 41, 59, 67, 68, 69, 76, 80, 91, 92

WMS Work Managment System. 34, 71

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Chapter 1

Introduction

1.1 Prelude

There has always been a tension between labor and technology. The tension is caused by a threat: the threat of labor being replaced or devalued by technology and thus labor losing the necessary for survival.

The story of this tension usually starts with the Luddites. A simple recounting sounds like this: in the early nineteenth century, a group of textile workers known as the Luddites destroyed textile machinery which they believed was a threat to their livelihoods (Binfield 2015). The Oxford English Dictionary (OED) defines a *Luddite* as 'one who opposes the introduction of new technology, especially into a place of work.'

A slightly deeper telling of the story reveals more. Many of the machines that Luddites targeted had been around for hundreds of years, yet there had been no previous attacks by labor (Conniff 2011). Binfield's *Writings of the Luddites* shows that attacks focused only on textile plants that skirted labor practices in a 'fraudulent and deceitful manner.' Further, Luddites 'just wanted machines that made high-quality goods' and for 'machines to be run by workers who had gone through an apprenticeship and got paid decent wages.'

The Luddites did not oppose *technology*. Rather, they opposed *how technology was used in their workplace.*

The parable of Luddites pits labor against technology. This is because the Luddite movement occurred before Karl Marx more astutely characterized the real target of Luddite ire: Management (Anderson 2019).

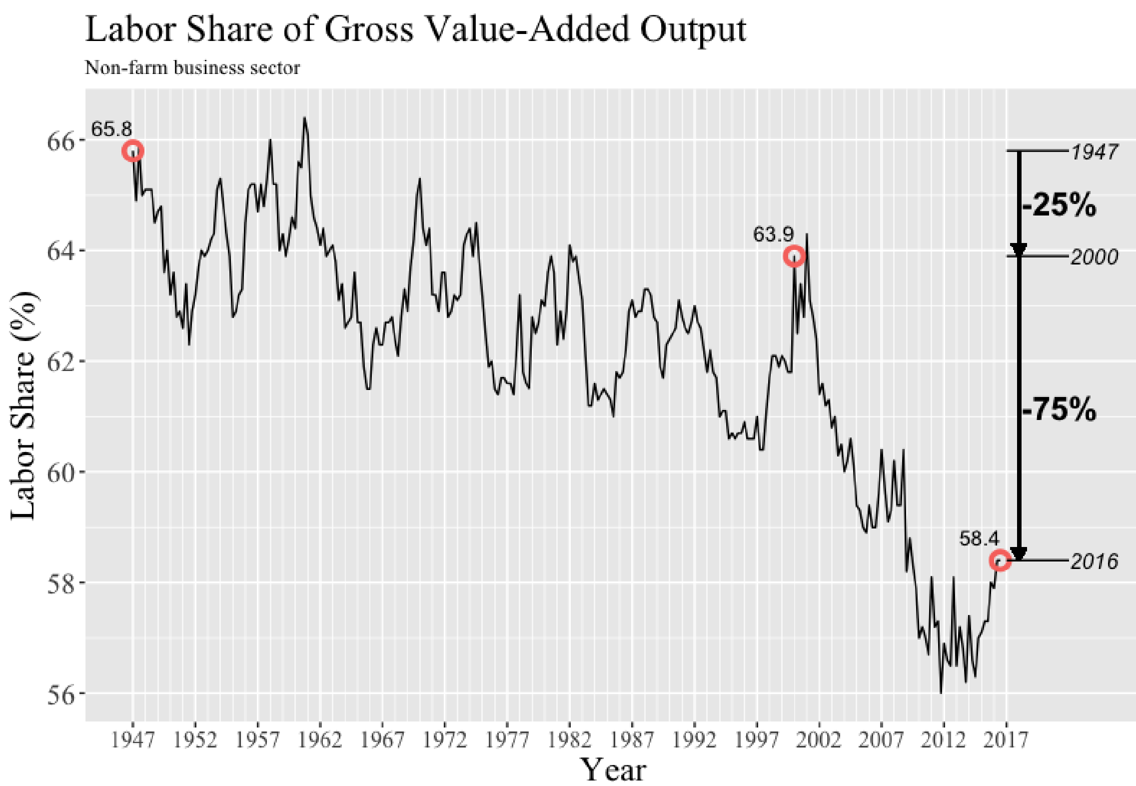
1.2 Context, Motivation, & Purpose

1.2.1 Context

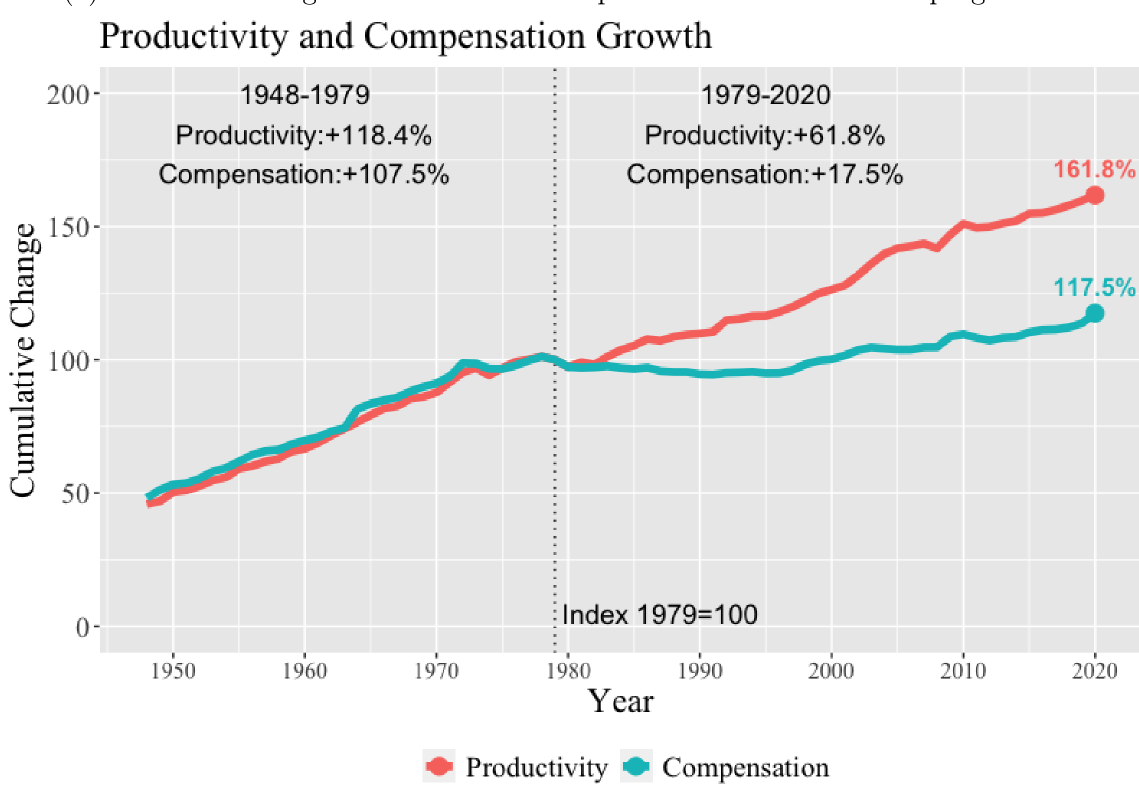
Today, it is *digital* technologies that are transforming the workplace. Computing power has followed Moore's Law for over 50 years (doubling computing capacity roughly every 18 months), enabling mathematical analyses that a human alone could never do (Mack 2011). Mobile devices and video conferencing, further enshrined into our workplace by COVID-19, enable us to 'stay connected' from anywhere at any time. Data are being collected at a rate of 4.4 zetabyes per day from customers, workers, sensors, operations, markets, and websites (Desjardins 2019). Data are easily and cheaply stored in the cloud for a variety of purposes. Artificial Intelligence (AI) and Machine Learning (ML) are competing or exceeding in tasks that were once solely the realm of humans (Mozur 2017). Digital platforms (sometimes called the 'gig economy') seem to be transforming not just where the workplace can be, but the definition of workers (*Prop 22* 2020).

While there may be contributing factors besides digital technologies, the fact that the labor share is declining and the wage gap is growing is worrisome for workers (Figure 1-1). Giandrea and Sprague 2017 explain why these metrics are important to workers and how they are related:

> [The labor share] is of interest to workers because it both describes the degree to which they are compensated for their efforts on the job and directly compares the output they helped produce with the compensation they received.
>
> Furthermore, changes in the labor share help explain the extent of the 'wage gap' between growth in labor productivity and growth in real hourly



(a) Labor share of gross value added. Adapted from Giandrea and Sprague 2017.



(b) Labor productivity & wage growth. Reproduced from Economic Policy Institute 2021.

Figure 1-1: Economic context for workers.

compensation[1].

1.2.2 Motivation

Underpinning the dynamics between labor, technology, and management is a fundamental question that motivates this research: *Who decides what, whether, and how technology is used in the workplace?* Even more broadly, who decides where technological value accrues?

This thesis examines a specific United States (US) labor policy intervention, technology bargaining, *as a potential means to answer the question*: Who decides what, whether, and how technology is used in the workplace? More specifically, it examines technology bargaining between labor and management in today's information age through two questions:

1. Why are digital technologies *more* relevant to the labor-management relationship than other technologies?

2. What is labor's current perspective on technology bargaining in the information age?

1.2.3 Purpose

The purpose in answering these two research questions is to identify potential means to improve the existing collective bargaining process.

Other countries use alternative means to answer the fundamental question (*Who decides what, whether, and how technology is used in the workplace?*), such as codetermination or regulatory (i.e., labor) law. Even if the US could 'start fresh,' the dynamism of collective bargaining may be best suited to match the emergent properties of digital technologies.

[1]Besides labor share, changes in the wage gap can be caused by differences between the output deflator and Consumer Price Index (CPI) deflator. Figure 5 in Giandrea and Sprague 2017 shows that differences in price deflators accounted for nearly all of the wage gap differences from 1973–2000. From 2000–2015, majority of the wage gap is driven by a decline in labor share.

1.3 Research Approach

Information used to conduct this thesis was gathered from three primary sources.

First, a literature review was conducted. Basic key word searches were done using a variety of academic databases and legal journals to identify relevant peer-reviewed literature. Literature recommended or written by informants was also included. The literature review returned a relatively limited set of results concerning the history and case law of technology bargaining. There is no shortage of literature on how digital technologies will affect workers and shape 'the future of work.'

Next, a list of labor related organizations – trade unions, governmental labor bodies, non-governmental organizations, and university departments focused on work, labor, and/or employment – was compiled (Appendix A). Their websites were explored to identify relevant policy proposals, policy analysis, position papers, presentations, or other publications that relate to technology bargaining in the information age. These sources returned a multitude of rich, varied, and relevant information that focused not just on technology bargaining, but also the related aspects of workers' rights and the impacts of digital technologies.

Finally, unstructured discussions were conducted with key informants (Appendix B) regarding technology bargaining in the context of the information age. Naturally, the discussions on technology bargaining reflected the background, area of expertise, and vantage point of each informant (e.g., law, technology, political science, union strategy and negotiations). The intent of using unstructured discussions is to 'get a current perspective' on technology bargaining as it is perceived today.

1.4 Structure

Chapter 2 provides background on a number of topics relevant to this thesis. Chapter 3 defines digital technologies and makes the case that they have influenced the production process, which is becoming 'taskified' and 'digitized.'

Chapters 4, 5, & 6 highlight the effects of a taskifed and digitized production process on labor demand and the labor-management relationship. Chapter 4 revolves around the negative effects of substitution and suggests that it will remain a dominant aspect in collective bargaining. Chapter 5 is centered on the potential positive effects of substitution. A focus on complementary skills and tasks may strengthen the positive effects of substitution. How digital technologies exacerbate the existing imbalance of power in the labor-management relationship is the topic of Chapter 6.

Labor's perspective and response to bargaining in the information age is covered in Chapter 7. Chapter 8 concludes.

Chapter 2

Background

This chapter very briefly introduces key topics and concepts relevant to this thesis.

2.1 Production Process

A somewhat older description is that the function of labor is to use their skills to produce quality goods and services and the function of management is to direct, monitor, and discipline labor in the production process (International Labour Office 2006). Implicit is also a management function to dictate what the process looks like. A simplified version of the production process is shown in figure 2-1.

Historically, the dynamics between labor and technology in production are examined through factor aggregation[1]. Labor inputs ($jobs \times wage\ rate$) and technology inputs ($utilization \times cost\ rate$) are aggregated and compared to total output. This method of analysis is formalized in the Cobb-Douglas Production Function,

$$Y = AL^{\alpha}K^{\beta} \tag{2.1}$$

where

[1] Technology is used instead of the more traditional economic term – capital – to describe the second key factor of production. When referring to factors of production, capital and technology are used interchangeably.

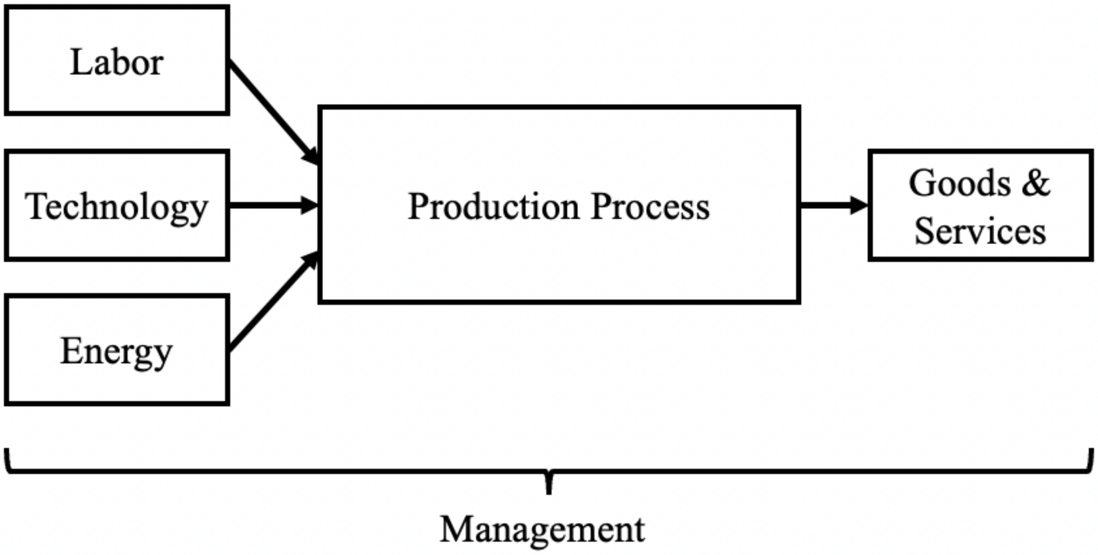


Figure 2-1: A simplified view of the production process.

Y = Total Output (Goods & Services)

A = Total factor productivity

L = Labor Input

K = Technology Input

α = output elasticity of labor

β = output elasticity of technology

Factor-based production processes are presented as a reference, but this thesis aims to demonstrate that the influence of digital technologies on the production process warrants a new task-based model of the production process (Chapter 3).

2.2 Production Performance

Economists and managers often use these input factors and outputs to report firm, industry, or economy-wide performance in the form of *productivity*. Productivity is simply the ratio of the total output of the production process over one (e.g., labor, technology) or all (total) factors of input. Labor productivity is still the dominant measure of performance used in the academic and business literature.

The conventional wisdom of classical economists, like Smith and Marx, states

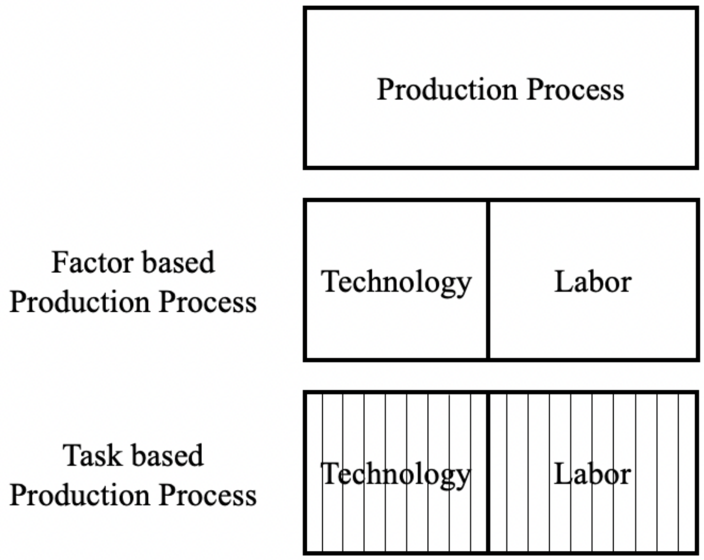


Figure 2-2: A simplified diagram of two different production process models. While some economists may include energy or other factors of production, this thesis primarily focuses on labor and technology inputs. Thus, other factors are omitted.

that the introduction of technology into the production process makes labor more productive. Labor productivity is *dependent* on technology (N. A. Ashford and Hall 2011).

Binary economics challenges this wisdom. A fundamental assumption in binary economics is that labor and capital are *independently* productive. This is best demonstrated with an example:

> Assume that in a pre-tool age, a person could dig a hole in four hours by hand. After the invention of a shovel, she can dig the same hole in one hour. In traditional economic terms, she has four times the productivity because she can perform four times as much work in the same time period. In binary economic terms, the productiveness has changed from 100% labor before the invention of the shovel, to 25% labor and 75% capital after the employment of the shovel. 75% of the worker's former productiveness has been replaced by an equal amount of capital productiveness (Robert Ashford via N. A. Ashford and Hall 2011).

A key aspect of this thesis asserts that both labor productivity and productiveness misinterpret the dynamic between labor and technology. While it is relatively straightforward to estimate task costs (Chapter 4), apportioning and quantifying value when labor and technology work together within a task (the shovel cannot dig a hole by itself!) or between complementary tasks is subjective and thus ought to be resolved through collective bargaining (Chapter 5).

2.3 Collective Bargaining

Senator Robert F. Wagner was cognizant of the unequal power (Chapter 6) in the labor-management relationship. In 1932, he appealed to his colleagues in the US Senate:

> By permitting labor to organize freely and effectively we can convert the relation of master and servant into an equal and cooperative partnership, shouldering alike the responsibilities of management and sharing alike in the rewards of increasing production (Wagner 1932).

Just a few years later, the National Labor Relations Act (NLRA) of 1935 (sometimes referred to as the 'Wagner Act') was passed and set the legal framework for labor-management relations in the US. N. A. Ashford and Ayers 1987 explain the rationale and scope of the framework:

> The duty to bargain collectively underlies the American labor relations system. Congress predicated the NLRA on the expectation that private negotiations will reconcile the divergent interests of management and labor while protecting the freedom of choice and efficiency of the marketplace. [...] The legislative history provides evidence that Congress intended collective bargaining to have a dynamic and expansive scope designed to meet changing problems arising from labor-management relations.

Congress' intent for a 'dynamic and expansive scope' is evidenced by their inclusion of language in Section 8(d) of the NLRA. Added as part of the Taft-Hartley

Amendments in 1947, Section 8(d) requires employers and employees to bargain 'with respect to wages, hours, and other terms and conditions of employment' (*NLRA* 1935).

2.4 Technology Bargaining

Smith and Marx realized that technology can have major effects on workers and their working conditions (Anderson 2019). This having been understood, workers may be keen to have some role in its adoption in the workplace.

2.4.1 Definition

Technology bargaining is a policy that would make explicit the duty to bargain over the *introduction of technological change* in the workplace (N. A. Ashford and Ayers 1987). Technological change is broadly defined. It could encompass physical technology (e.g., new machinery, robotics, tools) and/or digital technology (e.g., computers, information systems, algorithms, etc.). Definitions of digital technologies are provided in Chapter 3.

2.4.2 Scope

The deliberately ambiguous language used in 8(d) that *was intended* to broaden the scope of bargaining has had the *opposite effect*. In "Changes and Opportunities in the Environment for Technology Bargaining", N. A. Ashford and Ayers 1987 show that Congress' intent has been diminished through Federal and Supreme Court rulings, as well as rulings by the National Labor Relations Board (NLRB). The Courts and Board have narrowed the scope of bargaining by defining, often to the benefit of management, two key dimensions of bargaining – *subject matter* and *timing* (N. A. Ashford and Ayers 1987). These two dimensions of bargaining are essential in achieving the 'equal and cooperative partnership' envisioned by Wagner.

subject matter – what subjects *may* employers and employees bargain over? What subjects *must* employers and employees bargain over? These questions may be distilled into the concept of mandatory vs. permissive subjects of bargaining.

timing – when do employers and employees bargain over a subject? Must employers engage employees on a subject before making a decision or before implementation of the decision? A shorthand for these questions is captured in the concept of decision vs. effects bargaining.

N. A. Ashford and Ayers 1987 show that the technology is a permissive subject and that most times, excluding instances involving the health and safety of workers, only effects bargaining is required.

A full discussion of the judicial history that has shaped the definitions of what is considered a mandatory (vs. permissive) subject and what determines whether decision (vs. effects) bargaining is required is beyond the scope of this brief history[2]. What is important to recognize is this: superior bargaining power is afforded to management if the subject is permissive, but not mandatory, and the bargaining is over effects (such as displacement or changes in required skills).

[2]For historical court case and board decision analysis, see N. A. Ashford and Ayers 1987. More recently, see Rosenfeld 2018.

Chapter 3

Digital Technologies and the Production Process

Nicholas Negroponte, founder of the Media Lab at the Massachusetts Institute of Technology (MIT), famously described a shift in technological focus 'from atoms to bits' (Negroponte 1996). Brynjolfsson and McAfee 2014 further the distinction between the information age and previous industrial revolutions; the information age favors 'mind over matter, brains over brawn, and ideas over things.'

This first section of this chapter defines digital technologies and the emergent properties that differentiate them from physical or analog technologies. The next section will assert that the emergent properties of digital technologies have influenced the production process in two ways:

taskified – factors in the production process have been decomposed and modularized into tasks.

digitized – tasks, whether done by labor or technology, have been digitized.

This assertion lays the foundation to answer the first research question: Why are digital technologies *more* relevant to the labor-management relationship than other technologies?

3.1 Digital Technologies

Digital technologies, as defined for the purposes of this thesis, encompass a broad suite of interrelated and interdependent technologies. They are independently defined in Table 3.1[1].

technology	definition	primary function
computer	hardware that runs software.	*executes software*
software	instructions that tells a computer what to do.	*defines instructions*
internet	electronic communication network that connects computers and transmits data.	*connects computers*
data[2]	information in a computer readable form.	*stores information*

Table 3.1: Digital Technologies.

Broadly and simply defined, digital technologies include all of the devices that can gather, process, store, and transmit data in the workplace[3].

3.1.1 Emergent Properties

Six key properties emerge when examining digital technologies together as a *system*[4]. These properties are highlighted with examples or facts that reinforce their validity[5].

general – the 'general purpose' nature of computers and data has been profound. The number of personal computers, remote servers, and the 'computerization' of everything from telephones to toothbrushes is proof that computers truly are 'general purpose machines' (Figure 3-1a). Similarly, single data sets are being

[1]Digital technologies are juxtaposed with technologies that defined previous industrial revolutions in Appendix C.

[2]While data are not a *technology*, it is arguably what *defines* the Information Age. For convenience, data is included in the term 'digital technologies' used throughout this paper.

[3]While others believe Machine Learning (ML) and Artificial Intelligence (AI) ought to be defined as General Purpose Technologies (GPTs) (Crafts 2021; Brynjolfsson 2022), this thesis does not focus on where specific forms of technology can compete with labor and simply considers them another form of software.

[4]Further defined in Section 3.2.1

[5]These properties highlight the potential for greater efficiency and scope in the production process, but it must also be noted that the declining cost of computing power also contributed to their attractiveness. 'Total costs of computation in 2006 dollars per million units of computer power fell from 25.7 in 1940–9, to 0.000592 in 1970–9, and 0.000000000137 in 2000–6' (Nordhaus via Crafts 2021).

used in a variety of contexts. Weather data are reported for individuals to plan their day, used in commodity training, incorporated into agricultural operation decisions, and leveraged in climate change models (Figure 3-1b).

abstract – the abstract nature of software has led to an expansion of the scope of what technology has traditionally been able to do. Technology was previously only used as a means to augment human muscle. Software is now expanding into the realm of human cognition, and taking over tasks such as decision making, forecasting, recommendations, and others (Brynjolfsson and McAfee 2014).

modular – the deliberate modular design and interface standardization between digital technologies has enabled an explosion of hardware and software innovation, further supercharged by the next three emergent properties (Schwab 2017)[6].

replicable – the ability to easily replicate software and data makes the marginal cost of reproduction (what Leveson n.d. calls 'manufacturing') essentially zero.

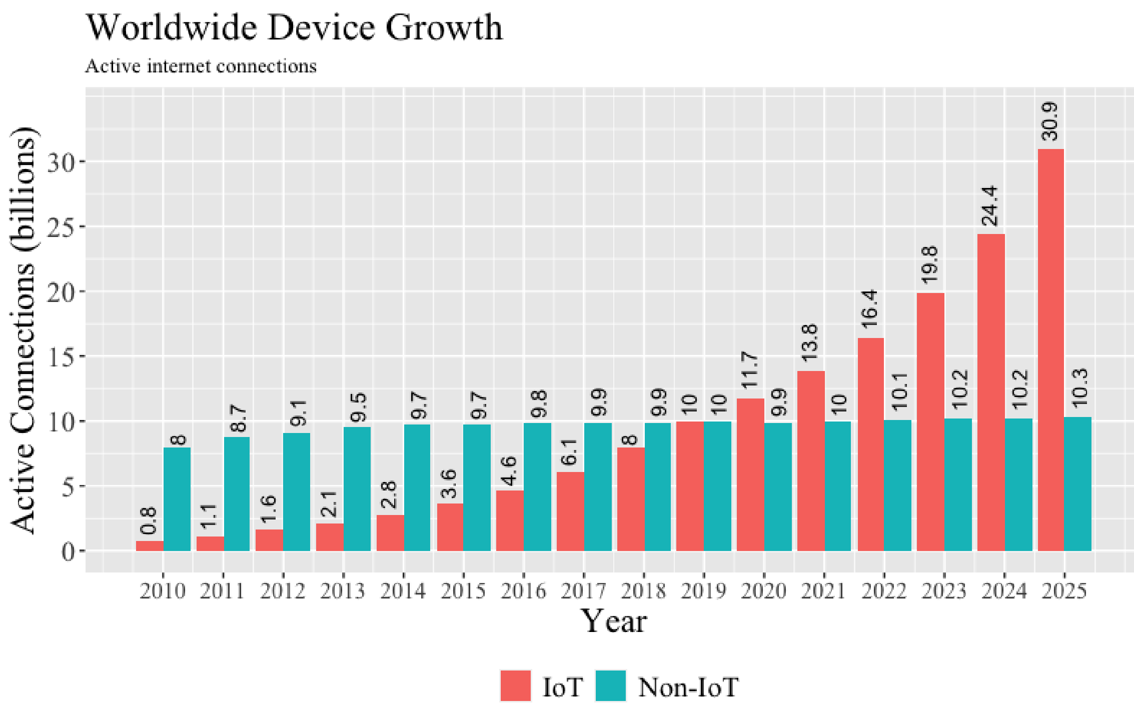
reusable – the ability to easily reuse software and data makes them extremely valuable. Neither is a consumable, depletable, or rivalrous. While software is often developed using the Single Responsibility Principle (SRP), data are more general purpose and can be used in a 'wide variety of contexts,' making it exceptionally valuable (Laney 2018).

instantaneous – atomic mass can move far faster than Newtonian mass. This simple physical property has enabled data and software to proliferate (via the internet) at tremendous speeds.

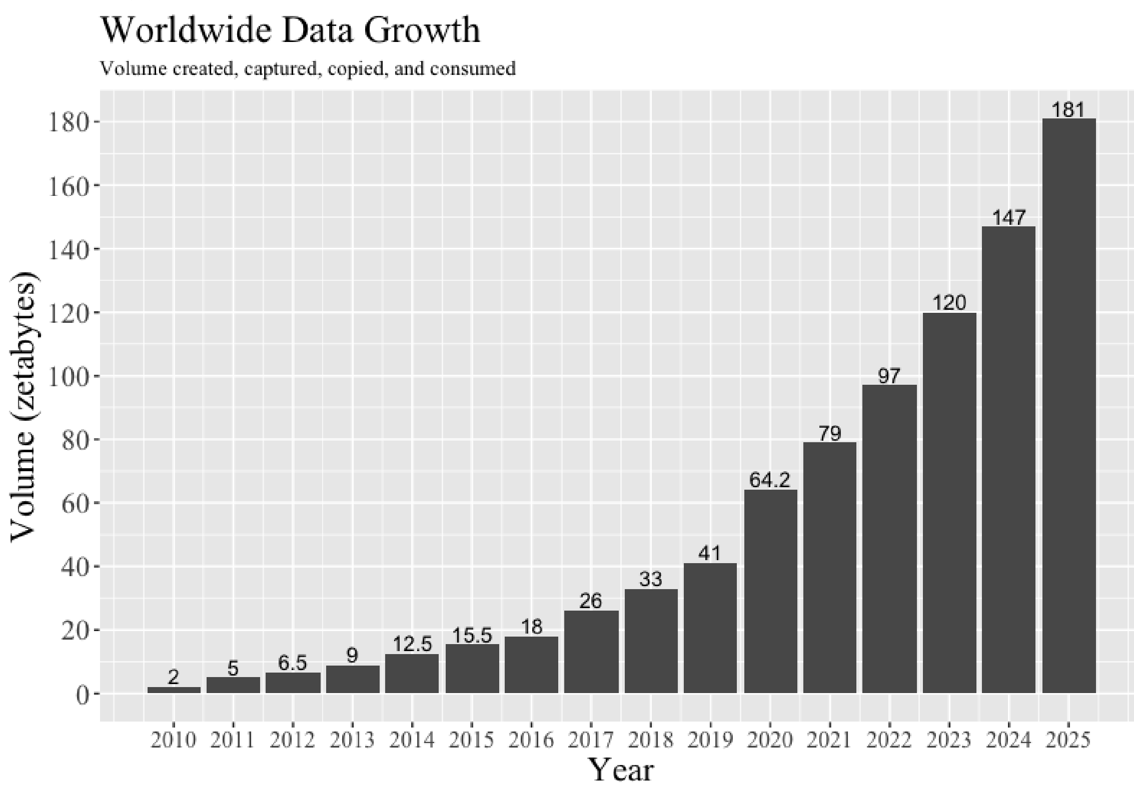
3.2 Influence on the Production Process

The production process required modification in order to take advantage of the desirable properties of digital technologies. Two emergent properties in particular – reusablility and modularity – influenced the nature of the production process in two ways:

[6] `computer::computer` via TCP/IP; `computer::software` via dominant chip architectures and OSs; `software::software` via SDKs and APIs; `software::data` via DBMSs and APIs.



(a) Active internet connected devices. Reproduced from Statista 2021b.



(b) Volume of worldwide data. Reproduced from Statista 2021a.

Figure 3-1: Growth of worldwide internet connected devices & data.

taskified – factors in the production process have been decomposed and modularized into tasks.

digitized – tasks, whether done by labor or technology, have been 'digitized.'

The intuition is simple: an element that is small, well defined, and compatible with adjacent elements is easier to trade, incorporate, and/or assess[7]. The subsequent sections of this chapter will support the assertion that digital technologies have influenced the production process.

3.2.1 System Design

The concepts of decomposition and modularization are system design principles. A system i) has elements ii) that interact with each other iii) to serve a purpose or objective (Crawley, Cameron, and Selva 2016). A common refrain in System Design is: *the whole is greater than the sum of its parts.*

Decomposition is the act of separating something (e.g., a product, service, organization, or production process) into smaller constituent elements. Modularization relates to the standardisation of elements, particularly with respect to i) repeatable production of elements and ii) interfaces between elements (Oxford English Dictionary 2019a, 2022b).

In *System Architecture*, Crawley, Cameron, and Selva 2016 define the Principle of Decomposition:

> Decomposition is an *active choice* made by the architect. The decomposition affects how *performance is measured*, how the *organization should be set up*, the potential for *supplier value capture*, and how the *product can evolve*, among many other things [emphasis added].

In the context of the production process, the 'active choice' of how to decompose the process into tasks is often made by management[8] and has major implications for

[7]These words reflect the language of Systems Design, which is introduced next. In subsequent chapters, these words will reflect the language of economics; substitution (Chapter 4), complementarity (Chapter 5), and monitoring (Chapter 6).

[8]Recall from Chapter 2 that unless there are issues involving health and safety, management is

value capture (who captures rents), evolution (how the firm and production process evolve), and performance (how it is defined and measured). Ominously, the authors summarize their principle with a roman quote: *Divide et Impera*; 'Divide and Conquer.'

Systems Influence on Digital Technologies

The field of System Design was born during World War II in the 1940's (Leveson n.d.). The size, complexity, and interaction between elements of technology overwhelmed traditional analytical methods. A means of designing and analyzing elements *together as a whole* necessitated the field of Systems Design. The development of computers and software occurred shortly after. Innovators in these fields both adopted from and contributed to the field of Systems Engineering (Leveson n.d.).

There are no canonical digital design principles that directly use the terms decomposition and modularity, but there are some oft-repeated software design principles that promote the two concepts. Some examples:

Don't Repeat Yourself (DRY) – extols consistency and reusability (promotes modularity).

Single Responsibility Principle (SRP) – every function, class, module, or service should have a single, clearly defined responsibility (promotes both modularity and decomposition).

Interface Segregation Principle (ISP) – software modules should be designed such that interfaces don't require unnecessary software modules (promotes decomposition).

3.2.2 Novel Evidence

Novel evidence demonstrates that the production process is in fact being taskified and digitized.

afforded the decision to change the production process. Appendix D.2 offers A Brief History of Employment Law, which is the source of this power, and is further discussed in Chapter 6.

in Governmental Data

The US Government first published the Dictionary of Occupational Titles (DOT) in 1938. It provided useful occupational information (e.g., job titles, job descriptions) for many jobs within the US but 'its usefulness waned as the economy shifted toward information and services and away from heavy industry' (Mariani 1999). In 1999, Occupational Information Network (O*NET) – a modern, flexible, database of occupational information – succeeded the DOT. Beyond titles and descriptions, O*NET includes thousands of tasks and task descriptions that are tied to jobs. O*NET is often used as the canonical source for job tasks in economic research.

in Economic Analysis

In a then groundbreaking paper, D. H. Autor, Levy, and Murnane 2003 presented this simple insight: jobs are simply a collection of tasks. Other economists have adopted this insight into their models and analysis.

In a pair of related papers, Acemoglu and Restrepo 2018, 2019 propose a new framework for examining the relationship between labor and capital in production processes. They move away from the simple factor-based production model and propose their own task-based production model. Tasks are declared 'the fundamental unit of production' (Acemoglu and Restrepo 2019). Their model and analysis of task-based production is introduced in Chapter 4.

Other influential research papers use tasks as the basis for their analysis. Frey and Osborne 2017 use a task-based approach to estimate that 47% of US jobs are at high risk ($P > 0.7$) of being 'computerised' in the next 10-20 years. Brynjolfsson, Mitchell, and Rock 2018 have similar findings. Both use O*NET in their research. McKinsey & Company 2017 also uses a task-based analysis (but not O*NET).

in the Production Process

While 'Roles & Responsibilities' are still used to define jobs in the workplace, tasks are more evident in actual production processes.

Labor Amazon workers are constantly 'reminded' if they have spent too much 'time off task' by their Warehouse Management System (Kantor, Weise, and G. Ashford 2021). HotSOS, a Work Managment System (WMS) used in the hospitality industry, also uses tasks as the basis of defining work. In WMSs such as Scrum – a task is the lowest level of work that can be defined (Schwaber and Sutherland 2020).

Companies are even using the term in their naming and branding (e.g., taskr and Task Rabbit)

Technology Software automation products use the term often, too. In Azure Pipelines, tasks are described as the 'building block for defining automation.' In Ansible they are at the bottom of an activity hierarchy, meaning that there is nothing smaller than the task (i.e., they are the fundamental unit of an Ansible Playbook).

No other product exemplifies the tasikification and digitization of the production process better than Amazon's Mechanical Turk Service. It is described as a means for firms to 'outsource their processes and jobs to a distributed workforce who can perform these tasks virtually.' It enables a task in a production process to be defined in computer code, sent to an available worker anywhere in the world, and have their task results/outputs returned to the digitized production process (Newman 2019).

3.2.3 Tasks, Digitized

A task – whether done by technology or labor – is considered 'digitized' if:

- The task is controlled or executed by digital technologies.
- Some aspect of the task execution is recorded as digital data.

Decomposition and modularity lead to 'small, well defined (and reusable) elements.' Digitization is what makes them 'compatible with adjacent elements' in the production process.

Recording some aspect of a task – who executed the task, when it was completed, how long it took – does not actually increase the productivity of that task; output and inputs remain the same[9]. This data can be used to enhance productivity of the

[9]Some examples of manual labor tasks being digitized would be completing a ride (e.g., Uber),

overall production process, among other things (e.g., monitoring. Chapter 6).

3.3 Taxi Example

A simplified but familiar example of a production process – taxi services – is presented in order to show how a production process can be taskified and digitized. In this section, just the decomposition is presented. A more detailed outline of Figure 3-2, showing how tasks could continue to be further decomposed, modularized, and digitized is available in Appendix E.

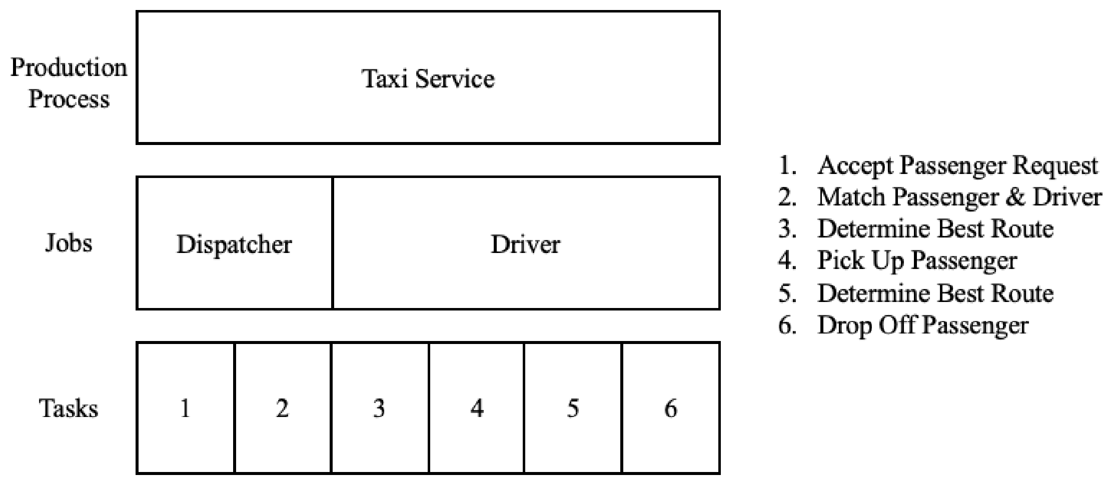


Figure 3-2: A simplified view of taxi service decomposition.

This examples begins with no digital technologies involved in the production process. Passengers still use telephones to request a ride from dispatchers. Dispatchers still use radio to communicate with drivers.

In subsequent chapters, additional aspects will be introduced to this example. How the changed nature of the production process affects labor demand, the labor-management relationship, and collective bargaining is examined in Chapter 4 (Substitution), Chapter 5 (Complementarity), and Chapter 6 (Unequal Power).

picking a package (e.g., Amazon), or writing a line of code (e.g., Scrum). Often, tasks completed by technology are already digitized because much of today's analog technology has a digital component (e.g., computer, sensor).

Chapter 4

Substitution

This chapter will show that the changed nature of the production process increases the *opportunity to* and *bias towards* labor task substitution. The chapter is organized as follows:

1. Section 4.1 introduces the concept of comparative advantage.
2. Section 4.2 defines and interprets the task-based model of production offered by Acemoglu and Restrepo 2018.
3. Section 4.3 explains why there are more opportunities for and bias towards labor task substitution.
4. Sections 4.4 describes the main negative effect of substitution – displacement. Subsequent decisions and positive effects are described in the Chapter 5.
5. Section 4.5 demonstrates the displacement effect by continuing to build on the Taxi Example introduced in the Chapter 3.
6. Section 4.6 concludes with a discussion on the implications for collective bargaining.

This chapter is not intended to be forward looking at where digital technologies can substitute or complement labor (for that research, see Brynjolfsson and McAfee 2014; Frey and Osborne 2017; Brynjolfsson, Mitchell, and Rock 2018). Nonetheless, Table 4.1 should give the reader a simple and intuitive framework to describe the *form of work* and *type of tasks* where digital technologies can complement or substitute labor (D. H. Autor, Levy, and Murnane 2003).

		Routine	Non-Routine
Manual	Examples	-Picking and sorting engineered objects on an assembly line. -Re-configuring production lines to enable short runs.	-Janitorial services. -Truck driving.
	Impact	Substitution feasible	Limited substitution or complementarity
Cognitive	Examples	-Bookkeeping -Filing/retrieving textual data -Processing procedural interactions/transactions	-Medical diagnosis -Legal writing -Persuading/selling
	Impact	Substantial substitution	Strong complementarities

Table 4.1: Potential Impact of Computerization on Four Categories of Workplace Tasks. Adapted from D. H. Autor, Levy, and Murnane 2003. The impacts of digital technologies may be different today. Advances in ML and AI have made many non-routine tasks ripe for automation. A number of widely used commercially-available tools that make automation feasible for non-routine cognitive tasks demonstrate this. For medical diagnosis, see: Esteva et al. 2017. For legal writing, see Bloomberg's Brief Analyzer. For persuading/selling, see Copy.ai. Separately, the same advances have enabled some non-routine manual tasks to seem feasible in the near future (see Tesla's Autopilot).

4.1 Comparative Advantage

Comparative advantage is the economic rationale used to explain when a factor of production should be substituted with another. A factor has comparative advantage over others in producing a good if it can produce that good at a *lower marginal cost* prior to trade (Thomas 2005). The same principle applies to tasks in a production process as goods in a market.

Using this rationale, it is easy to understand that when two factors (e.g., labor and technology) are able to do the same task, the one with the lower marginal cost is preferred (assuming equivalent volatility in both factors). The term 'automation' is used in the economic and business literature as a shorthand for when technology substitutes labor in a task[1].

[1] Automation is a specific form of substitution. As will be shown, labor can be substituted by other inputs. Given, this thesis will primarily use the broader term substitution. If the term automation is used, it is often to maintain consistency with the works referenced. The reader should understand it as a form of substitution.

4.2 Task Based Production

4.2.1 Definition

Recall the Cobb-Douglas production function from Section 2.1, where output $Y = f(A, K, L)$. Acemoglu and Restrepo 2018 update it to define output

$$Y = \left(\int_{N-1}^{N} Y(z)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}} \tag{4.1}$$

$$Y(z) = \begin{cases} A^L \gamma^L(z) l(z) + A^K \gamma^K(z) k(z) & \text{if } z \in [N-1, I] \\ A^L \gamma^L(z) l(z) & \text{if } z \in (I, N] \end{cases} \tag{4.2}$$

Y	$=$ Total Output (Goods & Services)
N	$=$ Number of Tasks, normalised between $N-1$ and N, indexed by z
σ	$=$ Elasticity of substitution between tasks, where $\sigma \geq 0$
$A^{L,K}$	$=$ Factor-augmenting terms, which increase productivity of the factor uniformly in all tasks
$\gamma^{L,K}(z)$	$=$ Increase in productivity of a factor in a single task z
$l, k(z)$	$=$ Total factor (labor and capital) allocated to producing task z
I	$=$ Threshold of tasks that are feasible to automate, given current level of technology

Finally, the model assumes that $\frac{\gamma^L(z)}{\gamma^K(z)}$ is increasing with z, such that labor has a comparative advantage in higher-indexed tasks.

4.2.2 Interpretation

As technology increases in ability or falls in cost (across tasks, A^K, or within a task, $\gamma^K(z)$), labor tasks will be automated ($I \rightarrow I'$). As new tasks are created, labor will have a comparative advantage and capture these new tasks ($N \rightarrow N'$). These shifts are graphically depicted in Figure 4-1. The addition or subtraction of tasks to or from labor implies nothing about labor demand (Chapter 5) but necessarily implies a change in the *labor task content of production*.

The labor task content of production 'represents the share of tasks performed by labor relative to capital (adjusted for differences in labor and capital productivity across these tasks)' (Acemoglu and Restrepo 2019).

$$\Gamma(N, I) = \frac{\int_I^N \gamma^L(z)^{\sigma-1}dz}{\int_{N-1}^I \gamma^K(z)^{\sigma-1}dz + \int_I^N \gamma^L(z)^{\sigma-1}dz} \tag{4.3}$$

Mathematically, this is represented in Equation 4.3. Graphically, this is represented in Figure 4-1 as 'the length of *Labor* divided by the length of *Labor* + *Capital*.'

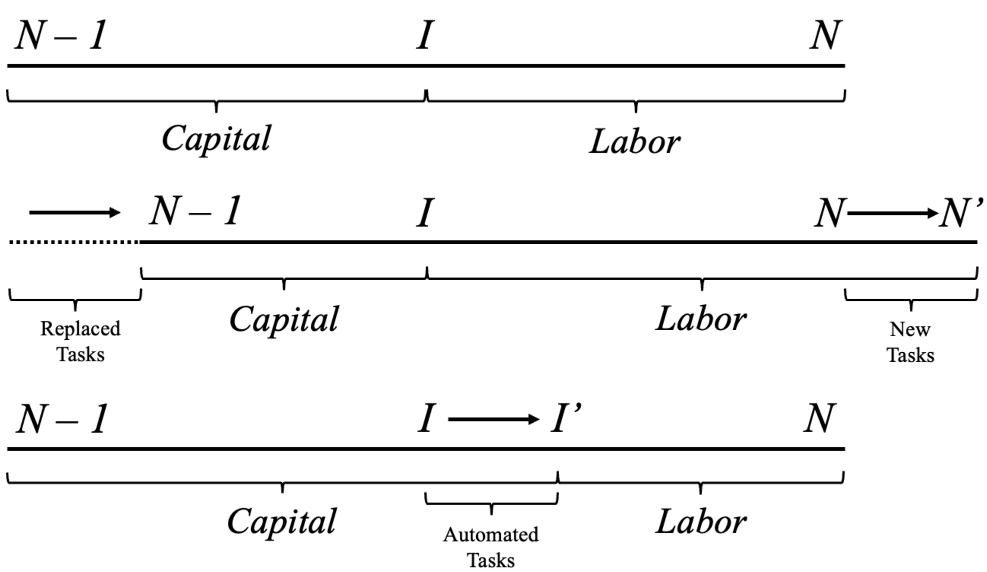


Figure 4-1: Changes in task content of production. Adapted from Acemoglu and Restrepo 2019.

4.3 Bias Towards Substitution

The arithmetic is simple. By breaking the production process into smaller tasks, the number of tasks increases. Every new task presents management another *opportunity to* decide to substitute. While the decision may not always be taken, a number of factors bias management towards the decision.

4.3.1 Divergence from Comparative Advantage

In the context of the labor-management relationship, N. A. Ashford and Hall 2011 note additional considerations beyond lower marginal cost that bias management towards the decision to substitute:

cost stability – the marginal costs of labor and technology are variable. Management may choose to substitute technology for labor even at a higher marginal cost to have more predictable costs.

factor ownership – management prefers to own the factor of production doing the task (see binary economics) and consequently may pay more to employ technology, despite higher marginal costs.

4.3.2 Technology

Acemoglu 2021 highlights a number of reasons technology is favored over labor:

labor market imperfections – firms make decisions based on the wage rate. A firm will substitute labor for technology even if that does not increase outputs or reduce input costs. A utilitarian social planner maximizing net surplus would recognize that the marginal cost of labor is zero and would retain workers.

business models – many firm's business models are centered around automation.

managerial preference – managers have a preference for reducing input costs over increasing quantity or quality of output.

tax code – the US tax code gives preferential treatment to capital over labor.

academic research – present academic research focuses on 'human parity' in 'narrow tasks' (a sentiment echoed in Brynjolfsson 2022).

4.3.3 Other Input Factors

Technology is not the only factor that can substitute labor. The digitization and taskification of the production process has also enabled management to substitute labor tasks with *customers and contractors.*

customers – a prime example of this would be self-checkout kiosks at retail and grocery stores. The marginal cost of a customer doing a task is zero. If tasks are small, well-defined, and can be done with little or no training[2], digital technologies can enable additional substitutes for certain labor tasks in the production process.

contractors – 'fissuring' is used to separate work from employment (Weil 2017 via Rogers 2020). While this strategy is legitimate and can benefit workers (flexibility is most often cited), it can also be used to undermine employment standards and avoid labor law (Rosenblat and Stark 2016). Fissuring occurs in two ways: tasks are outsourced to independent contractors or subcontracted to third party agents. The Theory of the Firm[3] states that 'firms have greater incentive to produce goods in-house and to control production tightly when it is difficult to specify outputs with precision or to monitor outside parties' performance' (Coase 1937; Rogers 2020). Taskification leads to precise definitions while digitization affords them the opportunity to monitor. The result is that firms can avoid paying some of the cost of employment (e.g., health benefits, workers compensation insurance, etc.) and sometimes avoid the costs associated with owning and maintaining physical capital (e.g., cars, tools, etc.).

4.3.4 Relative Objectivity

Acemoglu and Restrepo 2018 understand the issue with the classical economic interpretation of labor productivity mentioned in Chapter 2.2.

> It is clear that automation does not directly augment labor; on the contrary, it transforms the production process in a way that allows more tasks to be performed by machines.

Estimating and comparing marginal costs of a factor in order to make a substitution decision is relatively straightforward. As tasks become more defined, it becomes easier to assess individual task costs in a relatively objective manner. Labor costs can

[2]And customers do not complain.

[3]This theory is discussed further in Chapter 6.

be easily calculated or estimated as *wage rate* $\times$ *duration*. Technology cost estimation is also becoming easier[4].

Supreme Court interpretations of the NLRA favor this relatively objective, 'purely economic' justification[5]. This relative objectivity strengthens *managerial prerogative* to make substitution decisions[6].

4.4 Negative Effects

As technology increases in ability or falls in cost (across tasks, A^K, or within a task, $\gamma^K(z)$), technology may complete tasks at a lower marginal cost than labor. When this occurs and the decision to substitute labor with technology is made, the effect is labor displacement. Acemoglu and Restrepo 2018 call this the *displacement effect*[7].

To demonstrate this (without any other subsequent decisions or effects, which are introduced in the Chapter 5), the Taxi Example from Chapter 3 is continued.

4.5 Taxi Example

Figure 4-2 depicts the cost of each task in the sequence which they occur. The cost per task is calculated as the labor rate *for each task* times the duration of the task.

Task 2 requires valuable skills. A Dispatcher must know a great deal of information – the area and it's relevant attributes (e.g., traffic patterns, weather conditions, ongoing construction, accidents, etc.), the location and operating status of Drivers, and the location and time of Passenger Requests – in order to efficiently match a

[4]Whereas firms may have bought technology and would subjectively appropriate a fraction of the capital and operating cost to tasks, many digital technologies today are sold 'as a service' (e.g., Software as a Service (SaaS) and are best embodied by Microsoft Azure and Amazon Web Services). Depending on the technology, firms are even *billed* on a 'per use' basis, making it even easier to explicitly and objectively know granular technology costs.

[5]'Harm likely to be done to an employer's need to operate freely in deciding whether to shut down part of its business *purely for economic reasons* outweighs the incremental benefit that might be gained through the union's participation in making the decision' (*452 US 666* 1981).

[6]Managerial prerogative is a concept discussed further in Chapter 6.

[7]Although extremely tightly coupled, this thesis distinguishes the *decision* to substitute from it's direct *effect*: displacement.

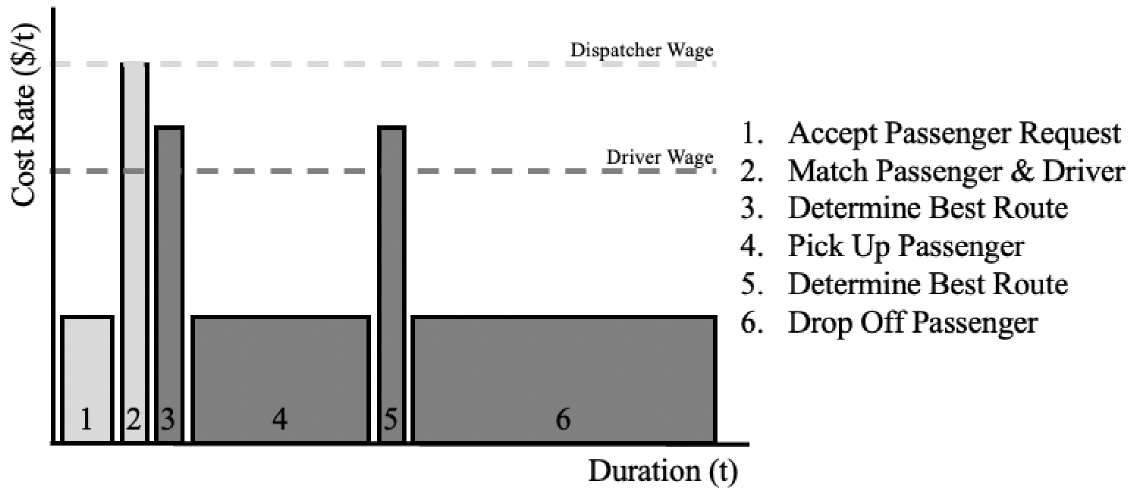


Figure 4-2: Labor Costs per Task and per Job.

Driver with a Passenger. Likewise, the Driver must have similar information in order to determine the best route in Tasks 3 and 5.

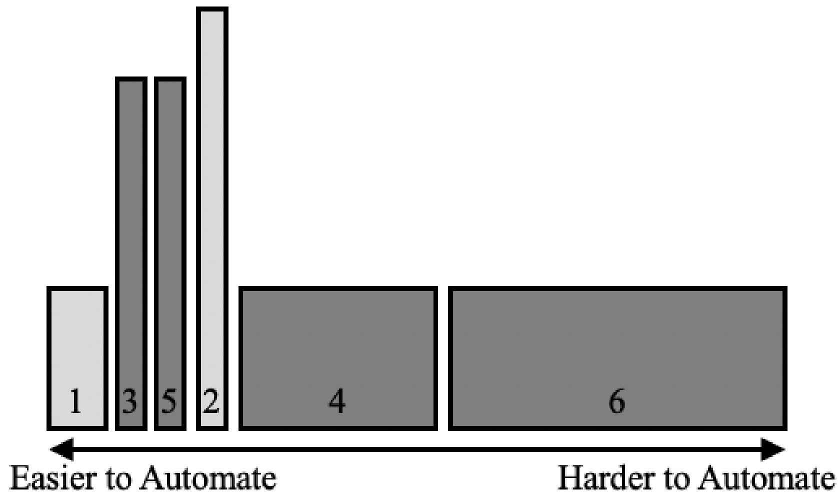
Tasks 1, 4, and 6 require less skill. Many people would be able to record a passenger request (e.g., name, phone number, location, pick up time) in a log. Given a route, many people are able to drive a vehicle.

Many jobs, though, do not pay on a per task basis. Given, the average wage of each job is also depicted.

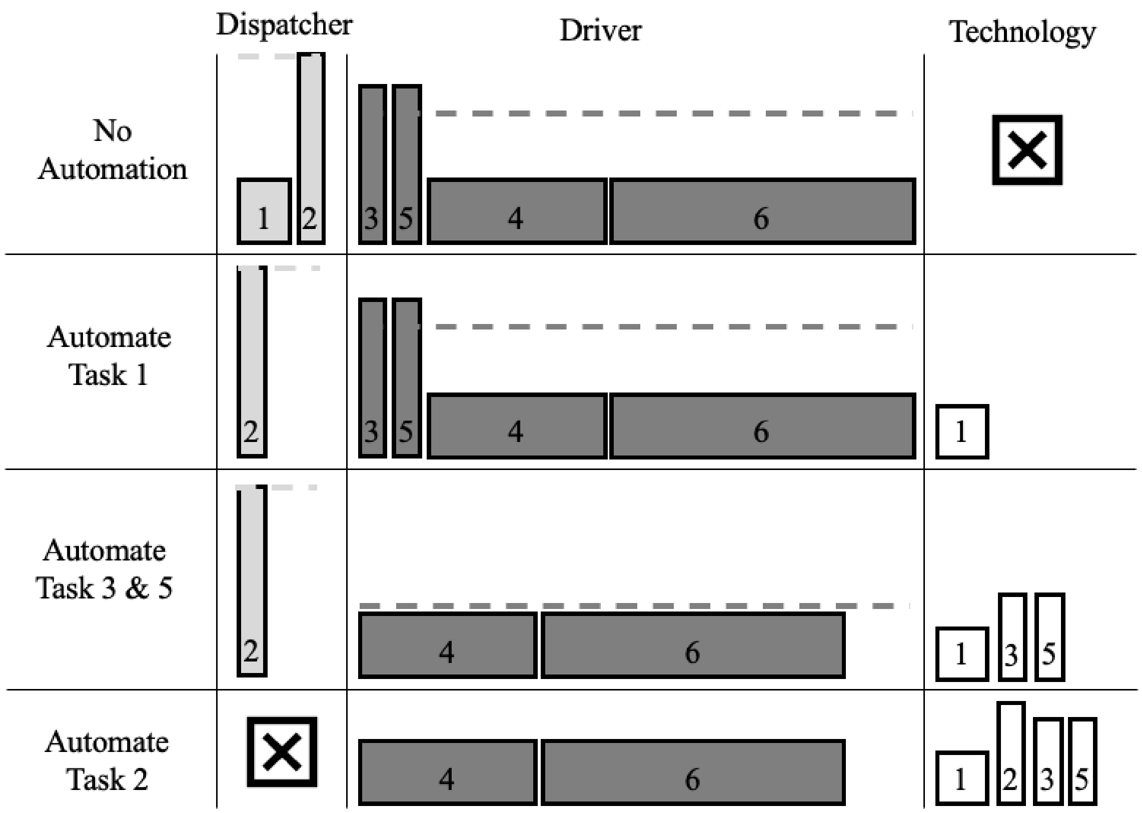
Before digital technologies, it was difficult to decouple these tasks from these jobs. The Dispatcher and Driver were able to command higher wages because of this. Any task cost *above* the wage line would be considered an economic rent going to the employer. Any difference below the wage line but above the task cost would be a rent captured by the worker[8].

Now, let us introduce digital technologies. Figure 4-3a simply reorders the six tasks according to their comparative advantage with technology. Task 1, Accepting Passenger Request is the easiest to automate. Tasks 4 and 6, Driving The Passenger, are not possible to automate with the current level of technology. To use the terminology of the task-based model defined in Section 4.2.2, I would be between Tasks 2 and 4 in Figure 4-3a. Figure 4-3b shows the displacement effects to each worker after

[8]The wage rates were arbitrarily chosen. They are a function of the labor market for those skills.



(a) Marginal cost of each labor task, reordered according to their comparative advantage against technology.



(b) Change in Task Ownership after Substitution.

Figure 4-3: Introducing digital technologies into the production process.

each task is automated.

1. After Task 1 is automated, both the Dispatcher and Driver are likely making the same wages as before. The only difference is that the Dispatcher is no longer capturing any rents. They only do tasks requiring their valuable skill set.
2. After Tasks 3 and 5 are automated[9], the Driver's wage is likely to decrease. They are not able to command a higher wage without Tasks 3 and 5; the remaining tasks can be done by less skilled drivers. The need for drivers remains, but the job has been *deskilled*[10].
3. After Task 2 is automated, the Dispatcher is no longer required in the production process.

This simplified example demonstrates the negative effects of displacement. For the Dispatcher, their entire job (as defined by Tasks 1 and 2) was automated away. The tasks that enabled the Driver to capture higher wages were automated, reducing their bargaining power and wage.

4.6 Implications for Bargaining

There are three main implications for bargaining that should be gleaned from this Chapter:

1. The changed nature of the production process has created more opportunities for management to be able to substitute labor tasks. Rather than major, visible changes to the production process, management can make many incremental changes to the production process.
2. There are known biases towards the decision to substitute. Substitution has dominated industrial relations in the past, and this is not likely to change in the information age.
3. The changed nature of the production process has made it easier to justify the

[9]They are automated together because they are very similar tasks. The reader might intuit that the digital navigation technology used was designed in a *modular* fashion so that it could be easily implemented in both tasks.

[10]See Appendix D.4 for A Brief History of Deskilling.

decision to substitute in relatively objective economic terms.

Packer 2019 captures the essence of how dynamics in the production process may differ in the information age[11]:

> Rather than labor annihilation, machine-human hybridization (labor-technology complementarity) appears to be AIs most likely medium-term outcome ... Fragmented workflows don't simply alter the labor economics of the firm – they transform the labor experience. The devastation of past technological revolutions was a blunt, destructive force that shredded labor demand and re-allocated the human capital of entire industries. That sledgehammer is being replaced by a scalpel: AI displacement of human knowledge work is selected, affecting only feasible sub-responsibilities (tasks) in certain jobs, and constitutes only a *partial* disruption.

[11]Translations into terminology aligned with this thesis are in parentheses.

Chapter 5

Complementarity

This chapter focuses on the potential positive effects of substitution.

Section 5.1 briefly introduces four additional positive effects defined by Acemoglu and Restrepo 2018. The positive and negative effects are examined collectively as sources of changes in labor demand caused by automation. Section 5.2 focuses on one positive effect – reinstatement. This thesis will suggest that focusing bargaining around complementary tasks and skills in the production process will be the best way to capture positive reinstatement effects. Section 5.3 focuses on another positive effect – productivity. While it is relatively straightforward to estimate task costs (Chapter 4), apportioning and quantifying value when labor and technology work together on complementary tasks is more subjective and thus ought to be resolved through collective bargaining. Section 5.4 summarizes the implications for bargaining.

5.1 Sources of Change in Labor Demand

The previous chapter stated that the substitution of labor tasks implies nothing about labor demand but *necessarily* implies a decline in the labor task content of production. This section will introduce four positive effects highlighted in the task-based model presented by Acemoglu and Restrepo in order to examine the net effects of automation on labor demand.

5.1.1 Positive Effects

While the displacement effect negatively affects workers, Acemoglu and Restrepo 2019 define four countervailing positive effects of automation that soften the negative effect of displacement:

productivity effect – as the cost of automation decreases, the economy will expand and increase the demand for labor in non-automated tasks.

capital accumulation – automation requires capital. As the cost of capital increases, this may also increase the demand for labor.

deepening of automation – automation does not just replace labor. It can replace existing capital in use, too. This creates a productivity effect but does not displace workers. This would thus increase the demand for labor.

reinstatement effect – the creation of new tasks in which labor has a comparative advantage relative to machines would increase labor demand.

5.1.2 Net Effects

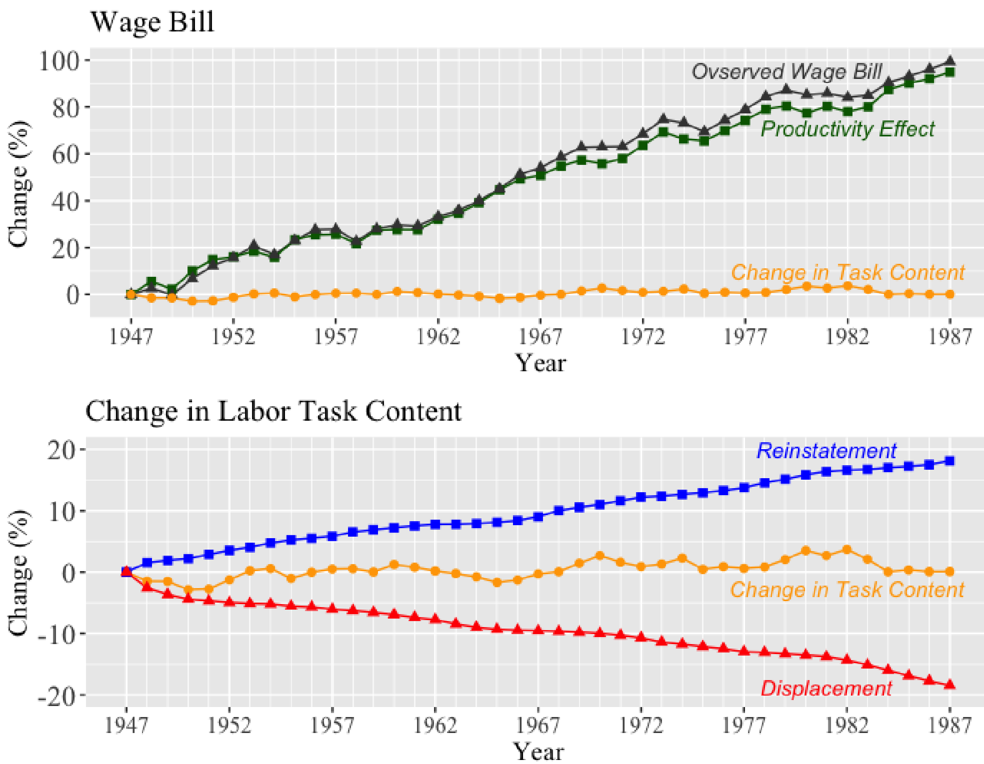
There have been tremendous amounts of automation in the past, yet the creation of new labor tasks continued to create demand for labor. If labor is displaced due to automation but fully reinstated in new tasks, the labor task content of production would remain constant.

Figure 5-1 demonstrates that this was the case in the second half of the twentieth century and is graphically depicted by the orange line hovering around zero. At the turn of the century, the labor task content of production began to decline.

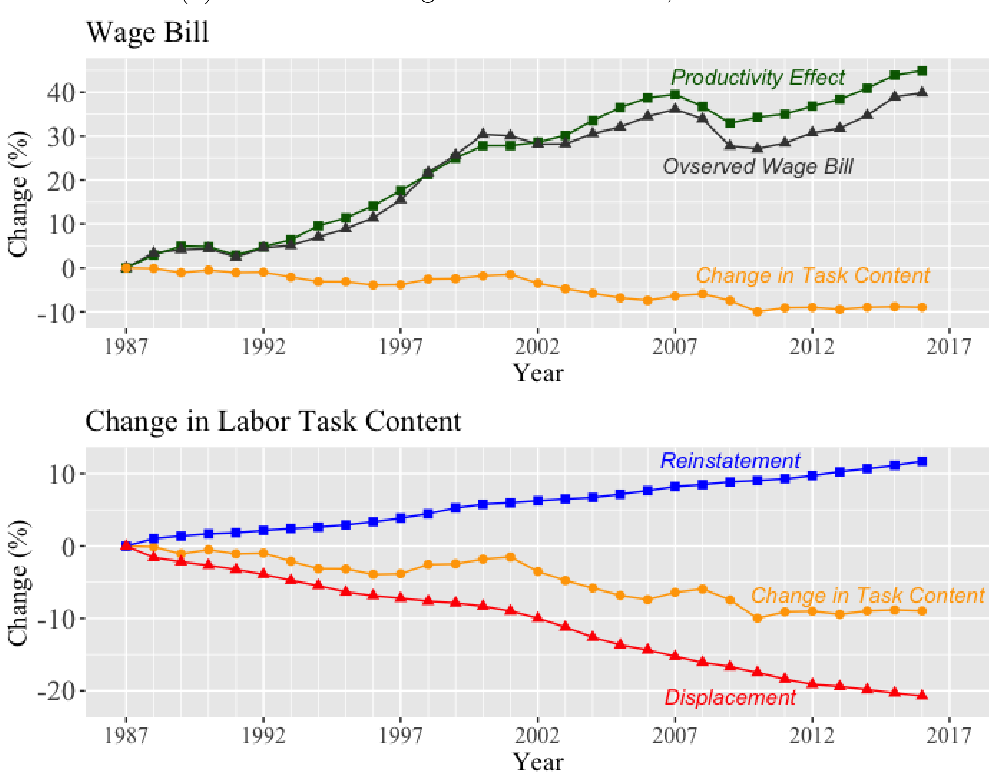
5.1.3 Analysis

The results can roughly be described by Equation 5.1[1].

[1] The substitution effect represents the factor augmenting productivity across the economy. The composition effect represents changes in employment between sectors. Neither have much of an effect and are thus not discussed.



(a) Sources of change in labor demand, 1947–1987.



(b) Sources of change in labor demand, 1987–2017.

Figure 5-1: Sources of change in labor demand, 1947–2017. Reproduced from Acemoglu and Restrepo 2019 using PlotDigitizer.

$$
\begin{aligned}
\Delta \text{ wage bill} &= \text{productivity effect} + \Delta \text{ labor task content} \\
\Delta \text{ labor task content} &= \text{reinstatement} - \text{displacement}
\end{aligned}
\tag{5.1}
$$

Increases in value add (shown by the productivity effect) are captured by labor (shown by the observed wage bill) when Δ labor task content $= 0$. When the labor task content of production went negative around 2000, the wage bill began to separate from productivity. This accurately reflects the change in labor share depicted in Figure 1-1.

What explains this increase in displacement relative to reinstatement?

Acemoglu and Restrepo 2018, 2019; Acemoglu 2021 believe *excessive automation* is to blame and note that this can be especially pernicious for labor.

> In contrast to the popular emphasis on the negative labor market consequences of "brilliant" and highly productive new technologies set to replace labor (e.g., Brynjolfsson and McAfee 2014, Ford 2015), the real danger for labor may come not from highly productive but from 'so-so' automation technologies that are just productive enough to be adopted and cause displacement, but not sufficiently productive to bring about powerful productivity effects.

What explains the slowdown in productivity growth?

Brynjolfsson, Rock, and Syverson 2018 examines a wide body of research to rationalize the optimistic and pessimistic views. Four explanations are proposed:

false hopes – the optimists are wrong.

mismeasurement – the past data is wrong.

concentrated distribution – strong productivity growth occurred, but only for a select few. Both optimists and pessimists are right and wrong to some degree.

implementation and restructuring lags – the time it takes to implement new technology and restructure the production process delays productivity growth. Both optimists and pessimists are right and wrong in a sense.

The authors favor the fourth explanation and argue lags in productivity occur because i) it takes time for a sufficient capital stock to accrue and show an aggregate effect and ii) *complementary investments* are needed to obtain the full benefit of the new technology (Brynjolfsson, Rock, and Syverson 2018)[2].

5.2 Complementarity

Brynjolfsson and McAfee 2014 do forecast that highly productive new technologies are on the horizon. But earlier work from Brynjolfsson also points to reasons beyond technology itself that strengthen productivity effects: complementary skills and complementary tasks.

Bresnahan, Brynjolfsson, and Lorin M. Hitt 1999 demonstrates that it often requires complementary investments (beyond the direct cost of digital technologies) to capture the full potential of a technology's productivity effects after it's introduced into the production process. These investments are often needed in the form of new skills for labor (reskilling) and new tasks in the production process (subsequent changes to tasks that interact with and complement the task being automated).

Brynjolfsson and Lorin M Hitt 2000 highlights the positive business performance earned by firms that make these complementary investments versus firms that only purchase technology.

While this research (and others from D. H. Autor, Levy, and Murnane 2003; Acemoglu and D. Autor 2010) suggests that the introduction of digital technologies into the production process will increase demand for skilled labor, little literature is specific about which combinations were implemented:

- existing workers with new skills
- fewer existing workers with new skills
- existing workers plus new workers with new skills

Neither management nor labor can claim to know what will increase productivity

[2] More recent empirical research using firm (not industry) level data favors the concentrated distribution argument (D. Autor et al. 2020).

effects more. The 'subsequent decision' – whether and how to reinstate labor – is not as straightforward as the decision to substitute labor.

In the Taxi Example from Chapter 4.5, there were no new tasks mentioned, though it is quite easy to imagine that a number of new tasks were created and skills needed. New tasks are needed to implement and monitor the technology used. New tasks would be needed to recruit drivers and market the new offering to customers. To do this, skills in software development and marketing (particularly in local markets) would be in demand.

Labor needs to recognize that complementary skills and complementary tasks are meaningful avenues to reallocate workers in the production process. Despite not being afforded the power to make or share in this decision by law, unions are not powerless in affecting the subsequent decision of whether and how labor is reinstated. Rather than resisting substitution, labor should aim to enhance complementarity in the production process.

5.3 Apportioning Value

Productivity – a simple ratio – misinterprets the dynamic between labor and technology. While it is relatively straightforward to estimate task costs (Chapter 4), apportioning and quantifying value when labor and technology work together in complementary tasks is more subjective and thus ought to be resolved through collective bargaining.

In classical economics, any new value created through the introduction of technology is apportioned to labor. In binary economics, any new value created through the introduction of technology is apportioned to capital. Neither is able to recognize a 'joint' productivity or productiveness because it is subjective.

As the production process becomes more taskified (i.e., decomposed into smaller and smaller parts), the value of *individual* tasks will approach zero. Individually, and without any complementary tasks, they may have little or no value. Value is generated when they interact with other tasks in the production process. Referring back to a common refrain in Systems Design: *the whole is greater than the sum of the parts*. The value created in these interactions is not easily or objectively attributable to any factor. As a result, value is not directly proportional to factor costs.

While this argument is not new to labor or management, apportioning value will be more complicated, relevant, and debatable as the production process becomes further taskified and digitized. Given, labor needs to consider this when bargaining. Whether and how the spoils of increased output are allotted (via wages or compensatory benefits) is a mandatory subject of collective bargaining.

5.4 Implications for Bargaining

The implications for bargaining in this chapter are summarized as follows:

1. New technology has both displaced and reinstated labor throughout history. A focus on complementary skills and tasks may strengthen positive reinstatement effects.
2. Apportioning value created to a factor in the production process is not objective nor directly proportional to factor or task costs. While this is not a new insight, it will be especially complicated, relevant, and debatable when bargaining in the information age.

Taken together, the implications of complementarity and substitution for workers is captured by a passage from "The Turing Trap" (Brynjolfsson 2022):

> The distributive effects of AI depend on whether it is primarily used to augment human labor or automate and replace it. When AI augments human capabilities, enabling people to do things they never could before, then humans and machines are complements. Complementarity implies that people remain indispensable for value creation and retain bargaining power in labor markets and in political decision-making. In contrast, when AI replicates and automates existing human capabilities, machines become better substitutes for human labor and workers lose economic and political bargaining power. Entrepreneurs and executives who have

> access to machines with capabilities that replicate those of human for a given task can and often will replace humans in those tasks.

The passage continues with a prelude to the topic of Chapter 6: Power.

> A fully automated economy could, in principle, be structured to redistribute the benefits from production widely, even to those who are no longer strictly necessary for value creation. However, the beneficiaries would be in a weak bargaining position to prevent a change in the distribution that left them with little or nothing. They would depend precariously on the decisions of those in control of the technology. This opens the door to increased concentration of wealth and power.

Chapter 6

Unequal Power

The Economic Policy Institute's (EPIs) Unequal Power Project is unequivocal:

> There is an inherent imbalance of bargaining power between employers and employees. There is, however, a pervasive assumption in economics, political science, law, and philosophy that this is a relationship of equal power. This wrong assumption diminishes freedoms in and out of the workplace and undermines legal protections in the workplace. It generates wage stagnation and inequality. And it undercuts civic engagement and representative democracy.

This chapter will first define power (6.1) and highlight the existing power imbalances between labor and management (6.2). Then, two ways in which digital technologies exacerbate this imbalance are examined (6.3):

1. Digital technologies centralize previously-distributed institutional knowledge about the production process. This centralized knowledge strengthens management's ability to **direct and control** the production process.
2. Digital technologies enhance the ability to **monitor and discipline** workers.

Chapter 7 explores how labor is responding to these imbalances as well as to the negative and positive effects of substitution outlined in Chapters 4 and 5.

6.1 Defining Power

The OED defines *Power* as 'control or authority over others' or 'the capacity to direct or influence the behaviour of others.' In adhering to the terminology used in the academic literature of political economy, this paper will adopt Weber's definition of power as one group's ability to 'realize their own will in a communal action against the resistance of others' (Rogers 2020).

6.2 Existing Imbalances

It is assumed that labor and management sit down at the bargaining table as 'self-interested actors, operating in perfect markets, with perfect information, and no [differences in] power' (Benkler 2019). This section will highlight these false assumptions to demonstrate that there is an existing imbalance of power.

6.2.1 Full Employment

Comparable bargaining power can only occur in the presence of full employment, which can be colloquially defined as 'anyone who wants a job can get one' (Cetty 2021). This has likely never occurred and can't truly occur without a federal 'job guarantee.'

Cetty 2021 summarizes the point nicely: 'If we do not in fact operate under full employment conditions, then maintaining an economic relationship with our employer may be dictated by necessity and is probably not consensual.'

When labor negotiates contracts with management, power is not equal without full employment. Rather, it is dependent on the strength of the current and forecasted labor market.

6.2.2 The Theory of the Firm

Avoiding the high cost of negotiating 'wages, hours, and other terms and conditions' is one of the main reasons firms exist (Coase 1937). Firms prefer to substitute contract negotiations with direct employment, and thus managerial prerogatives (refer to next section) in order to avoid going to market for every business task they require (Anderson 2019). They replace transaction costs with the cost of coordination[1].

Until there are 'perfect markets' for jobs and tasks, firms will continue to resist any contract negotiation that inhibits their managerial prerogative.

6.2.3 Managerial Prerogative

Management's power does not stem just from their position of strength in 'free markets.' Employment law also provides employers extensive powers to manage their workforce[2]. In common law countries like the US, longstanding legal statutes and norms enshrine these powers through the assumption of managerial prerogative (Deakin and Morris 2005; De Stefano 2018).

With regards to Section 8(d) in the NLRA, Tomasetti 2022 explains that

> if the employer refuses to bargain over these subjects, or makes a unilateral change regarding one of these subjects without bargaining, it breaches its duty under the NLRA . . . Thus, the NLRA expressly subjects employer prerogative to negotiation with the employees' union . . . The National Labor Relations Board (NLRB) has ruled that employers cannot rely on 'basic management prerogative' to make unilateral changes.

The Supreme Court had a different perspective. Much of the majority opinion in *First National Maintenance Corp. v. NLRB* (*452 US 666* 1981) revolves around *preserving* managerial prerogative.

> 'In view of an employer's need for unencumbered decision making in the conduct of its business,' employers must bargain where the 'benefit, for labor-management relations and the collective bargaining process, outweighs the burden placed on the conduct of the business.' The employer

[1]See Appendix D.1 for A Brief History of Management and the Modern Firm.
[2]see Appendix D.2 for A Brief History of Employment Law.

> ‘must be free from the constraints of the bargaining process to the extent essential for the running of a profitable business’ (Tomasetti 2022).

N. A. Ashford and Ayers 1987 identify many incongruities between this decision, the legislative intent of the NLRA, other Supreme Court decisions, and NLRB decisions. Recent research from Jager, Noy, and Schoefer 2021, 2022 on codetermination suggests that i) there is zero to modest positive impacts in firms that [share decision rights] and ii) the main benefit is [not shared decision rights, but] enhanced trust and information flows between labor and management.

6.2.4 Consequences of Non-Compliance

For employment and labor law to be effective, firms need incentives to comply. Penalties are one form of compelling firms to comply. But a purely profit (or power) maximizing firm may employ a familiar economic logic used in the decision to substitute: choose the lower marginal cost alternative. Comply if the expected costs of compliance are lower than the expected benefits (profit or power) of noncompliance.

Stansbury 2022 finds that

> a typical profit-maximizing firm, comparing the potential cost of paying back wages to the potential benefit of averting unionization, would have a compelling financial incentive to dismiss a worker for union activities – even if the firm *knew with certainty* that it would be caught and penalized by the NLRB – if this dismissal would reduce the likelihood of unionization at the firm by less than 2 percent, and perhaps by as little as 0.15 percent.

6.3 Exacerbating Imbalances

Recall the function of management defined by the International Labor Organisation (ILO) – to direct, monitor, and discipline workers. More and more, managerial tasks are also being substituted and complemented with digital technologies, too. Building on qualitative research of Uber from Rosenblat and Stark 2016, all three functions can be described with a real embodiment of the Taxi Example:

> An algorithm is used to direct which driver should pick up which passenger. If there are no passengers, a different algorithm directs drivers to areas it predicts will have future passenger demand. After picking up a passenger, the driver's phone transmits location and accelerometer data as a means to monitor driver performance (e.g., adherence to route, driving within the speed limit, executing smooth braking and turning). The passenger's rating and written feedback are also used as a means of monitoring performance, but also as a means to discipline workers. Poor ratings, complaints, or not accepting rides fast enough can trigger automatic consequences, such as deactivation or suspension from driving.

No technology since the telephone has likely made such an impact on 'management productivity.' Terms such as 'algorithmic management' (De Stefano 2020) and 'digital taylorism' (Rogers 2020) are apt descriptions for management in the information age. Two ways in which digital technologies exacerbate power imbalances between labor and management are:

1. Digital technologies centralize previously distributed institutional knowledge about the production process. This centralized knowledge strengthens management's ability to **direct and control** the production process.
2. Digital technologies enhance the ability to **monitor and discipline** workers.

6.3.1 Direction

'No human brain can contain even a small fraction of the useful knowledge needed to run even a medium-sized business, let alone a modern firm, so knowledge had to be distributed and decentralized[3]' (Hayek, via Brynjolfsson 2022). This institutional knowledge used to be a form of labor market power. When information about the en-

[3] See Appendix D.1 for A Brief History of Management and the Modern Firm.

tire production process becomes taskified and digitized, it can be 'owned, transferred, and concentrated very easily' (Brynjolfsson 2022).

In *The People's Republic of Walmart*, Phillips and Rozworski 2019 make a compelling case that companies like Amazon and Walmart are successful in part because they know *so much* about their production and distribution processes. Their market share is often cited as a form of power over their suppliers, but their superior information about their suppliers (and their supplier's competition) enhance their bargaining and purchasing power.

To summarize, centralized knowledge:

1. strengthens management's ability to make all of the substitution and subsequent decisions highlighted in Chapters 4 and 5 (e.g., change nature, sequence, or assignment of tasks).
2. devalues labor's institutional knowledge on the production process that was once a form of bargaining power.

6.3.2 Monitoring & Discipline

The need and desire to monitor workers predates digital technologies, but capturing and recording data about production process activity was infeasible or economically prohibitive. With a taskified and digitized production process, task data is available, if not abundant, with negligible marginal costs.

Monitoring Productivity

Arguably, management wants to capture task production data as a means to directly measure performance. When task production data directly impacts productivity (e.g., doing tasks faster is directly measurable in output), both management and labor may have a desire to use it as a means to i) incentivize workers and ii) demand a share of increased performance (Anderson 2019).

Whether and how the spoils of increased output are allotted (via wages or compensatory benefits) is a mandatory subject of collective bargaining. Yet this information is not always transparently shared with labor.

Monitoring Effort

Digital technologies can offer other means of monitoring workers that have nothing to do with productivity[4]. A plethora of software tools to record and/or report keystrokes, phone conversations, browser history, webcam footage, and other worker information have been adopted, spurned by COVID-19 (Rosenfeld 2018; Berhnhardt, Kresge, and Suleiman 2021). If it is not directly measuring or even improving productivity, why is it collected?

In large firms where tasks do not directly impact output, it is difficult to calculate the contribution to output of a single worker. Instead of monitoring output, management monitors *effort*.

Acemoglu 2021 explains that 'at the margin, monitoring is a way of shifting rents away from workers towards employers.' This claim uses insight from the then groundbreaking paper "Unemployment as a Worker Discipline Device", which further reinforces that full employment is not a reasonable assumption (Section 6.2.1) (Stiglitz and Shapiro 1984).

Algorithmic Discipline

Uber is not the only company to automate the managerial task of 'providing discipline.' When hotel room attendants did not complete tasks assigned by an algorithm fast enough, the HotSOS App on their iPads would audibly 'bark' at hotel attendants as a reminder to hurry up and finish the task (Winslow 2018)[5].

According to documents obtained by *The Verge*, a letter from an Amazon lawyer stated that 'Amazon's system tracks the rates of each individual associate's productivity and automatically generates any warnings or terminations regarding quality or productivity without input from supervisors' (Lecher 2019). To paraphrase a quote in

[4]A common example would be 'lines of code written' by a software engineer. A long, custom developed piece of software that is used once is not equivalent to writing a short package that is used multiple times. As such, 'lines of code written' is not a direct measure of output or productivity.

[5]This demeaning detail was shared during discussions with an informant (Appendix B).

the article, workers feel like robots because they are being managed by robots (Lecher 2019).

Chapter 7

Labor's Perspective

Since the passage of the NLRA, technology bargaining has not been a particularly popular or common policy intervention. This is evidenced by sparse academic research[1], limited union advocacy, and a dearth of congressional bills on the topic (let alone industrial relations in general).

The influence of digital technologies on the production process (Chapter 3) and their effects (Chapters 4, 5, & 6) have not forced a change in *law*, but there has been a change in *practice*.

Recent events demonstrate this. In 2018, Marriott Hotel workers bargained for and won provisions in their contract around technology. In 2022, Amazon workers won union recognition by organizing around, among other things, the digital warehousing software that directs, monitors, and even disciplines workers without human manager intervention (Lecher 2019)[2]. The Teamsters are preparing for a contract renegotiation with UPS in 2023 and have a strategy to negotiate over digital technology in their workplace (Rosenfeld 2018).

It then seems appropriate and timely to address the second research question: What is labor's current perspective on technology bargaining in the information age? Perspectives from various labor organizations and informants were generally aligned and can be summarised as follows:

[1] Rosenfeld 2018 agrees with this assessment.

[2] Discontent in IT companies has become so common that IT workers developed an action tracker: https://collectiveaction.tech/

1. **Legislation** is a long shot. It is very unlikely that technology bargaining will be strengthened through legislative or administrative means.
2. **Education** is lacking. Workers and managers do not adequately understand digital technologies. Both require significant education on the topic, especially in the context of the workplace.
3. **Bargaining** is still possible.
   - A lack of understanding presents both challenges and opportunities in contract negotiations.
   - Unions are prioritizing technology as a topic for bargaining, despite their relatively weaker legal position afforded by effects bargaining. Just because management is not required to bargain over the decision to adopt new technology does not mean that the decisions can not be brought into collective bargaining in practice.
4. **Data** is a source of power. Access to various forms of production process data can be used in a number of contexts of interest to labor.

Each subsequent section in this chapter will detail these perspectives. Because this chapter is intended to highlight labor's *current* perspective, recent informant discussions and labor organization literature will take prominence in the discussion, but older research will be mentioned when warranted. When aspects of the discussion were already public, informant names are included. Otherwise, they are simply referred to as 'informants.'

7.1 Legislation

Every informant favored stronger technology bargaining while simultaneously expressing little hope that technology bargaining would be strengthened as a matter of law in today's political climate.

Despite the perceived impossibility, some scholars and organizers (but no unions[3])

[3]The The American Federation of Labor and Congress of Industrial Organizations (AFL-CIO), despite setting up a Technology Institute in 2021, have no documented stance on technology bargaining.

still advocate for technology bargaining. Members of the University of California (UC) Berkeley Labor Center champion technology bargaining in their *Data and Algorithms at Work* Report (Berhnhardt, Kresge, and Suleiman 2021). Referencing this research, they make a case for worker data rights (including technology bargaining) in an open letter and public comment to the Office of Science and Technology Policy (OSTP) (Ajunwa et al. 2021; Bernhardt, Kresge, and Suleiman 2022).

While not expressly advocating for legislative change, two legal scholars have recently made compelling cases for technology bargaining versus other policy interventions (De Stefano 2018, 2020; Rogers 2020; De Stefano 2021). Both cite the dynamic and democratic nature of bargaining as preferable to plenary managerial authority or centralized governmental rule-making.

When asked about ways to use digital technology to strengthen labor, the US Department of Labor (DOL) Deputy Secretary, Julie Su, made no mention of changes to policy. Rather, she highlighted that digital technologies could be used to enhance organizing and reiterated that it is mandatory to bargain over technology with regards to health and safety.

Only relatively dated legal journal articles mention how Federal Courts and the NLRB could be used to strengthen technology bargaining (N. A. Ashford and Ayers 1987; English 1992; Abraham and Finzel 1997).

7.2 Education

Like most new technologies in the workplace, educating the workforce is usually a prerequisite before the technology can be adopted and used effectively. Informants discussed education from three perspectives – workers, managers, and unions.

7.2.1 Workers

Three informants focused discussions on worker education. Their justification for educating workers was simple: workers need to understand the benefits, costs, and risks of using digital technology in the workplace so that i) they can have an informed opinion on what, whether, and how digital technology should be used in their workplace and ii) are able to determine their own 'trades.' For example, workers might collectively agree to a digital monitoring system that they deem intrusive in exchange for other benefits. One informant felt that workers (and the public in general) did not perceive any negative effects of digital technologies until as late as 2015, when the Cambridge Analytica scandal unfolded during the 2016 US presidential election (Confessore 2018).

A 2018 survey on 'Worker Voice' shows that 52% of workers believe they ought to have more say on the 'Effects of New Technology' (Kochan et al. 2022). While the survey did not include questions on 'Decisions about New Technology' – it is notable that besides bread and butter issues like pay, benefits, and job security – new technology was the third highest topic that workers wanted more say on.

7.2.2 Managers

Three informants included discussion on managerial education. Their rationale centered around legal aspects – namely liability and compliance. The modular and reusable nature of digital technologies enables and encourages firms to purchase digital technologies from third parties. Understanding how third-party products work is crucial for managers to understand the impacts and liability. One informant advocated that *risk* assessments were not sufficient and suggested that labor could demand a *rights* assessment in order to learn more about the products being used in the workplace.

7.2.3 Unions

Three informants believe that unions, more so than workers and managers, would benefit from education on digital technologies. Unions could benefit in two ways. First, they could leverage digital technologies as a means to organize workers. Second, union representatives responsible for contract negotiations could garner a superior bargaining position with a better understanding of digital technologies than their counter party (which is discussed further in the next section).

Dr. Christina J. Colclough, founder of The Why Not Lab, has developed a number of app-based tools and guides to organize workers.

Thomas A. Kochan, Professor of Management at the MIT Institute for Work and Employment Research (IWER), is working with the AFL-CIO, the largest federation of unions in the US, to develop an online course titled 'Bringing Workers' Voice into Technology and Employment Strategies' (Institute for Work & Employment Research 2021).

A number of unions are developing courses and reference guides to assist in i) educating their members in general and ii) preparing representatives for contract negotiations (Stanford and Bennett 2021; Trades Union Congress 2021; Prospect 2022; United Electrical, Radio & Machine Workers of America 2022).

Notably, two informants mentioned that educating union representatives was insufficient for negotiations. One mentioned that their union was considering hiring a full-time 'Digital Representative' to advise the union generally and support contract negotiations specifically. Another retained an external 'Digital Advisor' throughout contract negotiations.

Their rationale for such roles is twofold. First, the workload of existing union representatives leaves little time for them to become sufficiently 'fluent' in digital technologies. Second, the pace of change and complexities of digital technologies warrant having a true subject matter expert.

7.3 Bargaining

Informants would prefer that all aspects of technology bargaining be mandatory. Despite the weaker bargaining position afforded by effects bargaining, unions have shown success in winning clauses around decisions and effects of technology in the workplace.

Kresge 2020 has catalogued and highlighted a number of successful collective bargaining agreements that involve clauses around the introduction of new technology.

Some unions have been successful in winning 'preemptive and decision making' rights, via labor-management cooperation clauses or joint labor-management committees. Others have negotiated clauses to limit the adverse effects of new technology through protection and transfer clauses, wage and benefit protections, and retraining programs. In Canada, Stanford and Bennett 2021 have also generated stock language to be used in collective bargaining agreements.

Carlos Aramayo pointed to an important clause in the 2018 UNITE HERE bargaining agreement that established a 'Technology Working Group' comprised of employer and union representatives. Before any new technology can be introduced, a 165 day notice must be provided, allowing the union time to review and assess the technology (Winslow 2018).

A bargaining strategy document written for the Teamster's by an 'offensive, aggressive' labor lawyer, cites a number of ways that effects bargaining can be enhanced. One notable example was exploiting events such as data breaches as a means to decision bargain over technology used in the workplace (Rosenfeld 2018).

7.4 Data

The topic of data was raised in all informant discussions and can primarily be described along two axis.

7.4.1 Worker Detriment

Using data for worker surveillance was raised in nearly all informant discussions. The challenge to negotiating over worker surveillance is that of 'purpose.'

An example was shared by an informant regarding cameras in worker vehicles. The union feared that cameras would be used as a means to monitor and discipline drivers. Management argued that the cameras were for safety (to ensure the driver was alert) and security purposes (e.g., if there was a theft or accident, footage could be used). Negotiating not just *whether* cameras can be used but *for what purpose* is possible, but difficult to enforce or prove.

7.4.2 Worker Benefit

Two informants raised the possibility of using data to benefit workers.

Hotel workers are concerned about safety from abusive guests. Rather than using historical complaint/incident data on guests to either i) ban guests entirely (which may reduce revenue) or ii) notify workers that guests have had previous reports of abuse (no reduction in revenue), the hotel operator opted to instead institute a new technology (panic buttons, which increased operational costs) as a means to increase worker safety.

In another discussion, an informant advocated that equal access to certain data may be used as an 'equalizer.' For example, schedule data (clock in and clock out times for employees) might be run through an algorithm to determine compliance with contract terms and employment laws. A recent interview with the president of the Amazon Labor Union revealed that one of their demands (when bargaining begins) is transparent access to productivity data in the WMS. This logic is echoed by Harari 2018: equal access to data can reduce information asymmetry and thus power asymmetry.

Lastly, it was noted that even with access to data, it cannot be assumed that unions have the ability to analyze or use data in beneficial ways.

Chapter 8

Conclusions

8.1 Findings

1. Digital technologies are influencing the nature of the production process; the production process is being 'taskified and digitized' (Chapter 3).
2. The negative effect of substitution – displacement – has been and will continue to be a prominent aspect of production process decisions and labor-management relations. The opportunity to, and bias towards, substitution in increasing in the information age (Chapter 4).
3. There can be positive effects of substitution, namely through productivity and reinstatement effects, but they are difficult to forecast and influence. Labor has traditionally resisted substitution, but may be served by focusing on enhancing complementarity to strengthen these positive effects when bargaining. Apportioning value to the factors of production that create output is subjective and will become more complicated, relevant, and debatable in the information age. Apportioning value, in the form of wages and compensatory benefits, is a mandatory subject of bargaining (Chapter 5).
4. The assumption that labor and management have comparable bargaining power when negotiating is wrong. Digital technologies exacerbate the existing power imbalance (Chapter 6).
5. Labor is beginning to recognize that *'this time is different.'* That technology is

being included in bargaining agreements and education on digital technologies is being prioritized is encouraging (Chapter 7).

8.2 Summary

Taken together, the continued drive towards substitution and increased bargaining power afforded to management by digital technologies may outweigh any positive effects seen in the labor market.

In order to achieve Wagner's original vision of the NLRA – *'an equal and cooperative partnership, shouldering alike the responsibilities of management, and sharing alike in the rewards of increasing production'* – it may be appropriate to consider making technology subject to decision bargaining.

Appendix A

Labor Related Organizations

A.1 University Research Centers

School of Industrial and Labor Relations (ILR) – Cornell University

https://www.ilr.cornell.edu/about-ilr

Institute for Work and Employment Research (IWER) – Massachusetts Institute of Technology (MIT)

https://iwer.mit.edu/

Labor Center – University of California (UC) Berkeley

https://laborcenter.berkeley.edu/

Data Justice Lab – Cardiff University

https://datajusticelab.org/

A.2 Non Governmental Organizations

American Enterprise Institute (AEI)

https://aei.org/

Economic Policy Institute (EPI)

https://epi.org/

National Bureau of Economic Research (NBER)

https://nber.org/

Ada Lovelace Institute

https://www.adalovelaceinstitute.org/

A.3 Governmental Labor Organizations

Department of Labor (DOL) – United States (US)

https://www.dol.gov/

International Labor Organisation (ILO) – United Nations (UN)

https://www.ilo.org/global/lang--en/index.htm

A.4 Trade Unions

The American Federation of Labor and Congress of Industrial Organizations (AFL-CIO)

https://aflcio.org/

Community Trade Union

https://community-tu.org/

European Trade Union Institute (ETUI)

https://etui.org/

European Trade Union Confederation (ETUC)

https://www.etuc.org/en

Prospect Trade Union

https://prospect.org.uk/

United Auto Workers (UAW)

https://uaw.org

United Electric (UE) Union

https://ueunion.org/

Appendix B

Informants

Thomas A. Kochan - discussion held April 13, 2022

George Maverick Bunker Professor of Management, Massachusetts Institute of Technology (MIT) Institute for Work and Employment Research (IWER)

https://mitsloan.mit.edu/faculty/directory/thomas-kochan

Valerio De Stefano - discussion held April 19, 2022

Associate Professor, Osgoode Hall Law School

https://www.osgoode.yorku.ca/faculty-and-staff/de-stefano-valerio/

Dr. Christina J Colclough - discussion held April 21, 2022

Founder, The Why Not Lab

https://www.thewhynotlab.com/

Carlos Aramayo - discussion held April 26, 2022

President, Unite Here, Local 26

https://www.local26.org/about/

Vice President, Massachussettes The American Federation of Labor and Congress of Industrial Organizations (AFL-CIO)

https://www.massaflcio.org/executive-council/carlos-aramayo

Lisa Kresge - discussion held April 26, 2022

Research and Policy Associate, University of California (UC) Berkeley Labor

Center

https://laborcenter.berkeley.edu/people/lisa-kresge/

Anna Mowbray - discussion held April 26, 2022

Research and Policy Officer, Community Trade Union

https://community-tu.org/author/amowbray/

Various Union Members - discussions held throughout June 17-19, 2022

Labor Notes Conference

https://labornotes.org/2022

Julie Su - question asked on July 14, 2022

Deputy Secretary of Labor, United States (US) Department of Labor (DOL)

https://www.dol.gov/agencies/osec/depsec

Washington Post Live: Future of Work and the Role of Technology

https://www.washingtonpost.com/washington-post-live/2022/07/14/deputy-labor-secretary-discusses-future-work-role-technology/

Appendix C

Digital Technologies

This Appendix provides more detail on the four individual digital technologies and compares them with technology from previous industrial revolutions.

C.1 Digital vs. Physical

C.1.1 Computers

The steam engine powered the first industrial revolution. It turned thermal energy into mechanical energy, a form of physical work.

Computers power the digital revolution. Comprised of semiconductors, transistors, and integrated circuits, computers manage the flow of electrons (Strickland 2009). Despite existing in the physical world, the technologies associated with the digital revolution are associated with mathematical and logical work.

Both the steam engine and the computer are hardware machines that provide a general form of 'work.' It is this 'general purpose' nature that makes these machines so important. Bresnahan and Trajtenberg 1995 define a GPT as a technology that is i) pervasive, ii) improves over time, and iii) leads to complementary innovations.

Despite the 'speed, control, power, and flexibility of this ... relatively small and light' general purpose machine, Leveson n.d. suggests that it is the 'complementary innovation' of software that takes full advantage of the general purpose computer.

C.1.2 Software

general purpose machine + customization = special purpose machine

The steam engine was augmented with train tracks and carriages to make locomotives. Workshop looms and mills were augmented with coal powered steam engines, precursors to the modern factory. Likewise, computers are complimented with software to make a variety of special purpose machines – such as games, business applications, or websites with myriad functions. What differentiates these customizations is their *form*. The steam engine is associated with physical work. As such, it's customizations – train tracks and looms – are also physical. Software – a set of instruction – is *abstract*. It's form fits the mathematical and logical nature of it's complementary general purpose machine. Leveson n.d. explains:

> Software is loaded into the computer, which, while executing the instructions, in effect becomes the special purpose machine. If changes are needed, the software instructions can be changed rather than building a different physical machine from scratch. Machines that previously were physically impossible or impractical to build become feasible. In addition, the design of a machine can be changed quickly without going through an entire retooling and manufacturing process. In essence, the manufacturing phase is eliminated from the lifecycle for these machines: The physical parts of the machine (namely the computer hardware) can be reused, leaving only the software design phase.

Whereas the customizations in the physical world are governed by the laws of physics, the abstract nature of software has no such governing principles. This nearly limitless scope of applications offered by the abstract nature of software has spurned much research and development in software. Crafts argues that algorithmic advances – such as ML and AI – will turn software into a GPT. Schwab 2017 believes that the 'sophistication and integration' of AI and existing digital technologies will usher in what he calls the fourth industrial revolution.

C.2 Digital vs. Analog

C.2.1 Internet

The second industrial revolution is defined by electrification. Electrical generators transform mechanical work into electricity – a carrier of energy (Tester et al. 2012). Rather than co-locate the general purpose machine with the customization, electricity carried through the electrical grid enabled the physical separation of the two. The electrical grid required major development of physical infrastructure to enable the transmission of electricity and standards to enable the use of electricity in a relatively uniform manner.

In many ways, the internet is similar to the electrical grid. It is a carrier of data. It required a tremendous build out of physical infrastructure (that looks very similar to electricity transmission infrastructure). It enables the physical separation of the things that it connects. Two aspects, though, differentiate these two networks.

machine-machine connections – whereas the electrical grid connects a general purpose machine with a customization to make a single special purpose machine, the internet connects a special purpose machines with one or more special purpose machines.

bi-directional connections – the transmission of electricity is uni-directional in the electricity grid. Electricity flows from the general purpose machine to the customization. The transmission of data is bi-directional via the internet. Data can be transmitted from any machine to any machine and vice versa.

The similarities and differences between the electrical grid and the internet diverge further when the things they distribute – electricity and data – are compared.

C.2.2 Data

Signals are a means of conveying information from one place to another . Generally, signals can be analog or digital[1].

[1]Up until this point, the term 'digital' has been used as a familiar, business-friendly shorthand for the more verbose and academic Information & Communication Technologies (ICTs). Only in

analog : *continuous* :: *digital* : *discrete*

An electrical signal such as voltage can be described as analog because it can take any real value within a range. Even with bounds, for example between -12V to 12V, there are an infinite number of real values that can describe voltage. Conversely, a digital signal can only be represented by N discrete values, where very often $N = 2$.

Computers convert analog electrical signals into a digital (discretized) signal. The conversion should be viewed as a simplification and standardisation of the signal. A continuous wave of real values (e.g., `4.57392944466890477`) is converted into a discrete number of binary values (`0`'s and `1`'s). While this does introduce some undesirable effects (Leveson n.d.), this conversion has many benefits – namely that the digital signal can be easily stored as (digital) data.

In *Infonomics*, Laney 2018 identifies a number of desirable properties of data.

storage – data is easily stored without error or degradation.

replication – data is easily replicated without error or degradation.

reusable – when used, data is 'non-depletable.'

processing – the binary nature of data complements the mathematical and logical 'work' of computers.

context – data alone has no context. Software can be flexibly designed to complement data in a variety of contexts.

transferable – via the internet, data can be transferred easily, instantly, securely, and without error or degradation.

Contrast data with electricity. Electricity can be used by a growing number of products and is transferable via an electric grid. But electricity is expensive to store, cannot be replicated, and is not reusable. This is why data is best thought of not as a technology, but as an asset. This is why The Economist calls it 'the world's most valuable resource.'

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this section is 'digital' used in it's proper technical context.

C.3 Digital Adoption

The opening salvo of Rosenfeld 2018 states 'There is nothing new about the obvious proposition that technology is changing the workplace . . . The real difference between then and now is the speed and breadth of change.'

The emergent properties outlined in Chapter 3 are certainly desirable, but the dramatic drop in the price of computing power further catalyzed adoption[2].

This speedy nature of adoption makes it more difficult for labor to assess and respond to the potential negative effects. The ubiquitous nature of adoptions makes digital technologies unavoidable. Both of these sentiments were echoed by multiple informants.

C.3.1 Speed

Crafts compares the adoption of digital technologies to other GPTs via growth in labor productivity. A simplified version of the equation that underpins the accounting is described in equation C.3.1.

$$\Delta\ Labor\ Productivity_{GPT} = \Delta\ Capital\ Deepening_{GPT} + \Delta\ TFP\ Growth_{GPT}$$

Capital Deepening can be viewed as a proxy for investment in the GPT and is used as here as a measure of adoption. Total Factor Productivity (TFP) Growth can be seen as the efficiency of that investment.

While it is an imperfect proxy, the speed of Information & Communication Technologies (ICTs)[5] adoption far outpaced that of technologies that defined previous industrial revolutions. It should be noted that the capital investment for steam and electricity is not only much smaller as a percentage of productivity, but the time span for which investment occurred was far greater; 150 years for steam, 140 years for electricity, and only 40 years for ICTs.

[2] Total costs of computation in 2006 dollars per million units of computer power fell from 25.7 in 1940–9, to 0.000592 in 1970–9, and 0.000000000137 in 2000–6 (Crafts 2021).

[3] Estimate does not take account of TFP spillovers.

[4] Estimate does take account of TFP spillovers.

[5] Digital Technologies should be understood to be synonymous with what Crafts calls ICTs.

	Capital Deepening	TFP	Total	% Whole Economy
Steam (UK)				
1760-1830	0.011	.003	0.014	5.6
1830-1870	0.18	0.12	0.30	19.0
1870-1910	0.15	0.16	0.31	29.2
Electricity (USA)				
1899-1919	0.04	0.06	0.10	5.6
1919-1929[3]	0.07	0.07	0.14	3.6
1919-1929[4]	0.07	0.30	0.37	9.5
1929-1941	0.04	0.16	0.20	8.0
ICT (USA)				
1974-1995	0.41	0.36	0.77	49.4
1995-2004	0.78	0.72	1.50	49.0
2004-2012	0.36	0.28	0.64	41.0

Table C.1: GPT Contribution to Labor Productivity Growth (% per year). Reproduced from Schweikl and Obermaier 2020.

C.3.2 Ubiquity

It is hard to imagine any company that has not adopted digital technologies in the workplace. A chapter title of *The Second Machine Age* describes it succinctly: 'The Digitization of Just About Everything' (Brynjolfsson and McAfee 2014).

A brief selection of papers that demonstrate this ubiquity are highlighted here. Additionally, some statistics regarding digital technology growth are highlighted to demonstrate that, despite achieving ubiquity *across* firms and industries, the *depth* of digital technologies will continue to grow.

- In their article "Digital Ubiquity", Iansiti and Lakhani 2014 note that traditional industries – such as agriculture, manufacturing, telecommunications, and banking – have been completely transformed by digital technologies. Further, what they call 'digital born' companies – such as Google (internet) and Microsoft (software) – have also been completely transformed.
- In a recent report titled *Data and Algorithms at Work*, Berhnhardt, Kresge, and Suleiman 2021 provide rich and detailed examples of how digital technologies have affected call centers, warehouses, distribution centers, home health care, traditional health care, retail and grocery stores, janitorial and security

services, the transportation sector, the hospitality industry, construction sites, and various aspects of the public sector.

- The entire cloud computing industry was created by the novel idea of 'renting someone else's computer' via the internet. BCC Research estimates that cloud computing generated $395B in revenue and will nearly double to $776B by 2026.
- There are roughly 10 billion active internet connected computers (phones, tablets, PC's, laptops, and fixed line phones) today. This is expected to remain constant through 2025. But the number of other devices, referred to as the Internet of Things (IoT) devices, is expected to grow rapidly from 13.8 to 30.9 billion in 2025 (see Figure 3-1a).
- A different report from Statista forecasts that volume of data created, captured, copied, and consumed worldwide will also continue to grow at an increasing rate, from 97 zetabytes today to 181 zetabytes in 2025 (see Figure 3-1b).

Appendix D

A Brief History

There are a number of topics discussed throughout this thesis that would be enhanced with a brief history. They are provided in this Appendix.

D.1 Management

Throughout the first industrial revolution, managerial duties (direct, monitor, discipline) were easily carried out in person because *firms were small*. Chandler 1977 shows that up until 1840, there was no such thing as a salaried manager; nearly all managers were owners. Essentially, there was just a single level of management co-located with, and often working alongside, their workers.

Chandler goes on to highlight how the development of railroads from the 1850's to 1880's revolutionized transportation and with it brought communication via the postal service, telegraph, and telephone. The geographic expansion of transportation and communication networks both necessitated and enabled coordination. The problem that necessitated coordination was rail traffic. To decrease traffic and increase throughput, coordination was required. The enabling of coordination – afforded by reliable movement of people, goods, and information – made management coordination more attractive than market competition[1]. Naturally, it is through this period

[1] This historical narrative – conflict, coordination, and cooperation – is better at explaining the evolution of markets than the simple and ahistorical 'rational actors' theory (Benkler 2019). It also is a prelude to Ronald Coase's Theory of the Firm (Section 6.2.2)

that the birth and growth of the modern firm occurs.

Modern firms needed people to coordinate within the firm (production) and beyond the firm (distribution). Thus, *management headcount grew*. It is this growth that led to today's hierarchical management structure. Rather than operate by 'The Invisible Hand' of the market, modern firms operate by the '*The Visible Hand*' of management (Chandler 1977).

D.2 Employment Law

Employment law provides employees basic rights such as a minimum wage, occupational safety standards, and medical leave. Employment law also provides employers extensive powers to manage their workforce. In common law countries, this is granted through the concept of *control* – the power to direct, monitor, and discipline workers. It is a key feature of and defining factor in employment relationships (International Labour Office 2006). In the United States, the 'nature and degree of control of the [employer]' is one of seven characteristics used to determine an employment relationship (Department of Labor 2022). In civil law countries, the notion of power is expressed through the concept of *subordination* (De Stefano 2018).

Whether through the concept of control or subordination, the power to manage the workforce is often referred to as *management's prerogative*. De Stefano explains:

> Deakin and Morris (2005) observe [that] managerial prerogatives 'do not simply result from the employer's superior bargaining power prior to the agreement.' They are 'underpinned by certain legal norms that today take the form of the common law implied terms of the contract of employment,' such as the employees' obligation of fidelity and obedience, 'which can be traced back in many cases to the master and servant legislation of the nineteenth century and before.'

The foundations of employer power in early British America is enshrined through case law that was heavily influenced by statutory law such as the Britain's Master and Servant Acts and imported to America in the nineteenth century (Naidu and Yuchtman 2013). As H.G. Woods so succinctly puts it in 1877, a decade after the US Civil War ended, 'all who are in the employ of another, in whatever capacity, are regarded in law as servants' (Tomlins 2004).

The pertinent point that De Stefano, Deakin, Morris, and Tomlin make is that managerial prerogatives are strong. They stem not just from superior bargaining power enshrined by a 'free market', but longstanding legal statutes and norms.

D.3 Labor Management Partnerships

There were three notable attempts in US labor history to develop a partnership between labor and management that have attempted – with different levels of success – to share decision rights between labor and management.

Treaty of Detroit – In 1949, the president of the United Auto Workers (UAW) Walter Reuther was dubbed 'The Most Dangerous Man in Detroit.' He was given this title because of his belief that the UAW should be part of production decisions and that the big three auto manufacturers (General Motors (GM), Ford, Chrysler) should open their books to the union. Despite Reuther's strong bargaining position in the post World War II era, the big three vehemently opposed the demand to share production decision rights. Ultimately, the UAW gave up on the demand to be involved in production decisions and instead extracted large pay and benefit packages for members. This landmark agreement became known as the 'Treaty of Detroit' for bringing stability to production and labor-management relations, but is also seen as the first (major and failed) attempt to develop a LMP (Loomis 2018).

Saturn – In 1983, the UAW and GM embarked on a radical and innovative experiment to co-develop a car company from scratch. In their book *Learning From Saturn*, Rubinstein and Kochan 2018 argue that it was a successful experiment by any number of measures. By its third production year, 'Saturn had become the quality, reliability, and customer-satisfaction leader among domestic automakers. At the same time, the Saturn plant became one of GM's most productive auto factories' (Belzer 2004). Despite high worker satisfaction, high customer satisfaction, and entering into the black a year ahead of plan, GM never did fully commit to the Saturn experiment (Hanna 2010).

Kaiser Permanente – In 1995, ten different unions joined together to create the Coalition of Kaiser Permanente Unions (CKPU) with the intent to collectively negotiate a labor contract with Kaiser Permanente (KP), the leading provider of private health care in the US. Rather than take an *adversarial* approach (like Reuther and the UAW), the CKPU decided to take a *cooperative* approach when negotiating their Labor Management Partnership (LMP or Partnership)[2].

The results are astounding. The LMP between the CKPU and KP is often lauded as the ideal case for labor-management partnerships in the US. A key tactic in their successful negotiations was *shared, interest-based* principles (e.g. patient care) (Eaton, Rubinstein, and Kochan 2008). The respect and commitment between both parties is evidenced by the brevity of their agreement (only 10 pages[3]) and the durability of the partnership (20 years and counting). The agreement's two foundational tools, consensus decision making and interest-based problem solving, are realized through innovative Unit Based Teams (UBTs)[4].

The Saturn Experiment and the Kaiser Permanente LMP demonstrate that there are (at least two) examples of firms deliberately choosing to partner (rather than fight, in the case of The Treaty of Detroit) with unionized workers to run successful businesses. Despite their success, the orthodoxy position in the private sector is resistance to sharing decision authority with labor.

[2]see https://www.lmpartnership.org/
[3]see https://www.lmpartnership.org/tools/kp-alliance-labor-management-partnership-agreement
[4]see https://www.lmpartnership.org/path-to-performance/ubt-basics

D.4 Deskilling

The OED defines *Deskilling* as the conversion of a workplace from one that requires skilled workers to one that does not; to reduce the number of skilled workers.

The concept is most often attributed in the academic literature with *Labor and Monopoly Capital* (Braverman 1974). The substitution of skilled workers with less skilled workers occurred in the workplace well before the book's publication. There are a number of means by which deskilling can occur, but Frey and Osborne cite two examples of deskilling from previous industrial revolutions that specifically highlight the principles of decomposition and modularization:

decomposition - [describing the Ford factory line] 'Work that had previously been performed by artisans was now decomposed into smaller, highly specialised, sequences, requiring less skill, but more workers, to perform.'

modularization - [describing the motive for interchangeable musket components] 'Eli Whitney, a pioneer of interchangeable [modular] parts, described the objective of this technology as "to substitute correct and effective operations of machinery for the skill of the artist which is acquired only by long practice and experience; a species of skill which is not possessed in this country to any considerable extent."'

Deskilling occurs in both instances. Notably only one involved technological innovation; the other involved changes to the production process.

In the Ford example, management simply chose to decompose the responsibilities of a single artisan into smaller tasks done by multiple workers. This increased labor productiveness (no new technology) yet reduced the need for skilled artisans. The development of the factory line was influenced by Fredrick Taylor.

Fredrick Taylor ceded nothing to workers. Taylor, who published *The Principles of Scientific Management* in 1911, believed that there was 'one best way' to organize work and that it was the function of management, not workers, to determine how work would be done. In many ways, Taylorism formalized the belief that in order to have the most efficient production – worker autonomy should be eliminated through the standardisation, order, and assignment of all work by *planners* (Moser 2021). This idea is most vividly exemplified in Henry T. Ford's assembly line.

In the Whitney example, the modularization of interchangeable gun components reduced the need for artisans to complete the task of component repair. The new task (replace the broken component with a new component) could be done by any soldier. The ability to create interchangeable gun components, was made possible by advances in technology.

Appendix E

Taxi Example

This Appendix offers additional detail relevant to the Taxi Example used throughout this thesis.

E.1 Decomposition

E.1.1 Level 1 – Jobs

1. Dispatcher
2. Driver

E.1.2 Level 2 – Roles

1. Dispatcher
    (a) Accept Passenger Request
    (b) Match Passenger & Driver
2. Driver
    (a) Pick up Passenger
    (b) Drop off Passenger

E.1.3 Level 3 – High Level Tasks

1. Dispatcher

(a) Accept Passenger Request
    i. Record time of request, passenger name, passenger pick up location, and passenger pick up time.
    ii. Add Ride Request to Passenger Queue.
(b) Match Passenger & Driver
    i. Review Passenger Queue
    ii. Review Driver Availability
    iii. Select Best Match
    iv. Notify Driver

2. Driver
    (a) Pick up Passenger
        i. Determine Best Route to Passenger
        ii. Drive to Passenger
    (b) Drop off Passenger
        i. Determine Best Route to Destination
        ii. Drive to Destination

E.1.4 Level 4 – Lower Level Tasks

Only a subset of Level 3 tasks are decomposed further. In reality, decomposition can continue.

1. Determine Best Route [to Passenger/Destination]
    (a) Retrieve Starting Point
    (b) Retrieve Ending Point
    (c) Retrieve Map area
    (d) Retrieve Traffic data
    (e) Identify 3 Alternative Routes
    (f) Rank 3 Alternative Routes by estimated Duration
    (g) Select Shortest Duration Route
    (h) Send Shortest Duration Route to Driver

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