A FORUM ON EMERGING TECHNOLOGIES

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As part of *ILR Review*'s new special series "Novel Technologies at Work," this article introduces a forum composed of five industry studies that examine the drivers and impact of recent and impending technological change. Each of the studies, condensed from longer reports published over the past two years, relies on interviews with sectoral actors and other primary data to determine the relevant technologies confronting workers and managers and the sorts of strategies and policies that will mediate their effects.

UNDERSTANDING THE IMPACT OF NOVEL TECHNOLOGIES AT WORK THROUGH AN INDUSTRY STUDIES LENS

ADAM SETH LITWIN AND JESSIE HF HAMMERLING*

> There certainly will be job disruption. Because what's going to happen is robots will be able to do everything better than us. . . . I mean all of us.
>
> —Elon Musk, July 15, 2017

> Excessive automation at Tesla was a mistake. To be precise, my mistake. Humans are underrated.
>
> —Elon Musk, April 13, 2018

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Among the hallmarks of pluralist industrial relations or the interdisciplinary study of work and employment is its groundedness in real industries and workplaces. What industry studies cede in generalizability they more than make up for in richness, credibility, and causality. Particularly when trying to make sense of novel phenomena, researchers are wise to swoop down from 30,000 feet to examine production and service delivery processes—essentially, the data-generation process on which subsequent, more deductive studies will rest. Had Adam Smith never visited that pin factory, who knows how he and then we would have theorized the division of labor?

And so it goes with our making sense of the impact of more recent technologies on work and workers. To date, both researchers and the media have focused obsessively on the question: Are robots and artificial intelligence (AI) coming for our jobs, undercutting pay and standards if not displacing most workers altogether? At their best, they build on existing theory developed in the wake of previous waves of technological change. Then they ask, are today's new technologies skill-biased, and thus most likely to harm low-skilled workers? Or, are they task-biased, and thus, likely to have a "polarizing" effect on the labor market (Autor, Katz, and Kearney 2006)? In the case of the assembly line, diffusion paralleled increases in wages and employment, buoyed by swelling product demand and powerful industrial unions that forced employers to share productivity gains with factory workers. By the time microcomputers diffused enough to catch labor economists' attention, information technology (IT) use was associated with increased demand and wages—but *only* for those workers who had completed high school. So, what will be the labor market impact of today's IT, AI, and robots?

In the spirit of this journal and of our field, we believe that a more complete understanding of the effects—realized or potential—of today's emerging technologies requires a closer examination of their sectoral contexts. To this end, Annette D. Bernhardt, PhD, of the UC Berkeley Labor Center partnered with Working Partnerships USA to commission a series of industry-specific reports on technological change in health care, trucking, warehouses, retail, and food delivery. Each research team conducted its study independently, but the Labor Center convened the researchers to develop a coordinated approach, framework, and set of objectives. The authors worked to generate concrete information for policymakers and other stakeholders about the industries and occupations in which employers' use of new technology has the potential to affect jobs and workers in the near and medium term, and where there may be alternative paths forward in the deployment of these technologies.

The authors of this forum have distilled their findings into the essays that follow. Each author identifies key technologies that are in use or "on-deck" in each industry—ranging from relatively simple improvements in internet and communications technologies and the digitization of information to complex machine learning-based technologies. They then address three questions: What factors motivate and influence employers' adoption of new technology? Which new technologies are most likely to be used by employers in ways that affect wages, skill requirements, and the organization of work? Finally, what are the potential consequences of employers' use of these technologies for the industry's most populous occupations, and how might these effects vary by race, ethnicity, gender, age, and educational attainment?

The overarching goal of the comparative project was to generate a set of related findings about technological change across key sectors of the economy. In contrast to conventional theories of technological change, these studies focus on sources of variation, identifying distinct processes and outcomes of technological change across and within industries. They illuminate the important influence of product and labor market institutions, and they show how variations in employer size, available resources, technological sophistication, and managerial capabilities lead to different capacities and choices regarding technology adoption.

Of course, the underlying context for each industry—the core US industrial relations framework—proves consequential. Employers in each industry we studied face a similar conundrum: How to use new technology in the context of overwhelming market pressures to reduce labor costs, speed up production, and exert increasing control over workers' activities. Despite the pressure on employers to adopt a "low-road" approach to new technologies across the industries we studied, the specific manifestations of this dynamic vary in meaningful ways with respect to the myriad factors driving and shaping technology adoption and its effects.

Even within a single industry, the impact of employers' use of technology on the quality of jobs and labor displacement is heterogeneous. In warehouses and in retail, for example, the largest employers are experimenting with the latest advances in automation and employee surveillance, while many smaller firms struggle to implement even the simplest systems for inventory tracking (see Gutelius and Theodore in this forum; Carré and Tilly in this forum). As we learn from Viscelli (in this forum), workers in different segments of the trucking industry face distinct technological threats: Autonomous driving technology is more easily applicable to driving over long stretches of highway rather than complex urban roadways, meaning that long-haul truckers face a greater risk of automation-based job loss compared to last-mile delivery drivers. Grocery store and restaurant owners have tried limited experiments with task automation, but many are using technology to facilitate surveillance, to transfer work from customer to worker and vice versa, and from employee to independent contractor (see Benner and Mason in this forum).

In this introduction to the essays, we highlight some of their key insights. We discuss important differences and common themes that emerged. To begin, we offer a brief overview of relevant theory on the labor market and workplace impact of technological change.

The Labor Market and Workplace Impact of Technological Change

The five industry studies essays draw on a common set of existing theories about technological change. We summarize them here.

Substitution versus Scale Effects

Perhaps understandably, researchers and journalists focus on employers' use of technologies as a *substitute* for labor. Basic economic reasoning posits that if the cost of technology falls relative to the cost of labor, that is, wages, then employers will shift their resources from labor to capital, thereby making production or service delivery more capital-intensive and less labor-intensive. Consequently, demand for labor would fall, eroding employment, wages, and job quality writ large. This process of technological *substitution* proved an important feature of 20th-century industrialization, offset by the expansion of product markets (e.g., Alexopoulos and Cohen 2016). But today, both popular and scholarly conjecture predicts substitution at apocalyptic levels (e.g., Ford 2015, 2021; Kaplan 2015; Frey and Osborne 2017). These accounts have had an outsized effect on the operative narrative around technological change, despite the emergence of more nuanced empirical and theoretical work (e.g., Acemoglu and Restrepo 2019).

Fortunately for workers, technological change permits an important secondary effect. By reducing the overall costs of production or service delivery, new technologies also allow employers to produce more than they had been able to, thereby allowing the *scale* of production to grow. This scale effect typically intensifies the use of all production inputs, including labor. As a result, in this case, the positive scale effects resulting from technological advances *at least partially* offset the negative substitution effects arising from those same advances. Which effect dominates—and therefore, whether workers benefit or suffer, in the net—thus becomes an empirical question. That said, scale effects have clearly dominated substitution effects, at least in the long run: While the Luddites really were displaced by the machines they feared, massive increases in demand ensured that their descendants found new work in textile production and eventually in other sectors. Still, determining how these processes unfold and for whom—that is, when, where, and why jobs are lost and created, and how workers actually experience these changes—requires rich, field-based industry studies.

Job Content and Quality Effects

Technological change affects not only the aggregate number of jobs but also their task composition and associated job quality. By the latter, we mean the bundle of extrinsic and intrinsic rewards, work intensity, working conditions, and interpersonal relationships that workers experience (Kalleberg 2011; Osterman and Shulman 2011). Close observers of the employment relationship have long opined that technological change would seemingly influence both the conditions of and returns to work. Technological determinism—the idea that changes in productive technology drive social and economic relations—forms the core of Marxist ideology, as best articulated by Karl Marx in *Das Capital* ([1867] 1990) and later by Harry Braverman (1974), Stephen Marglin (1974), and David Noble (1979, 1984), among others. To varying degrees, each thought technological change in a capitalist system inevitably favored employers over workers (or capital over labor), facilitating managers' efforts to shrink employment rolls, speed up work processes, de-skill jobs, and curtail wages.

Many institutional economists of the mid-20th century found this approach too limited to explain what they were observing. In general, US unions did *not* simply oppose technological change. Instead, unions responded in varying but predictable ways to management's modernization imperative. According to Sumner Slichter and his colleagues (Slichter, Healy, and Livernash 1960), unions often supported technological change if they could use it to bargain for higher wages and job security—key facets of job quality—and sometimes even employer-sponsored investments in lucrative new skills. Litwin (in this forum) points to these dynamics, in particular, around health care provider Kaiser Permanente's transition from paper-based to electronic health records (EHRs). These institutional theories, themselves the product of industry studies research, spawned a debate over whether and when technological change resulted in "upskilling" (providing workers increased earnings alongside their higher productivity) or "downskilling," akin to the processes described by the Marxists.

As computer- and internet-based technologies grew more widely available at the end of the 20th century, labor economists' attention turned to skill-biased technological change (SBTC)—the theory that new computational technologies boost the wages and employment levels of those with certain types of high-value skills and displace workers in jobs that do not require those skills. While Alan Krueger (1993) elevated this line of research, others advanced it by breaking jobs down into tasks, concluding that computers and other forms of IT excel at predictable, repeated tasks that could be easily coded into software (Autor, Levy, and Murnane 2002, 2003). As a result, people who do work of this sort would face shrinking opportunities in the labor market, along with eroded benefits and employment conditions.

This task-biased view of technological change thus allowed for variation in outcomes; however, the variation arose entirely from attributes inherent in the technology itself rather than attributes inherent in any of the humans involved in its deployment or use, or the institutions they create. While examples of task-biased technological changes are abundant, as an all-encompassing theory it is incomplete. Specifically, it ignores at least three fundamental issues. First, some changes in job content could involve altogether new tasks, themselves the result of a product or service facilitated by technological change, for example, online order picking and goods delivery (see Carré and Tilly in this forum). Second, existing, deductive approaches leave little or no room for employer or worker agency, especially over an extended time frame (e.g., Autor et al. 2002; cf. Hunter, Bernhardt, Hughes, and Skuratowicz 2001). Thus, this approach could not explain ostensibly similar technologies yielding dissimilar effects on workers contingent on business strategy, organizational characteristics, or sectoral context, for example. Finally, the theory of task-bias hinges on technological limitations that while reasonable at the time, now seem quaint.

Along Come "Smart" Technologies

The technologies of the 2010s differed substantially from those that came before them. They no longer required brute-force programing by human engineers forced to consider every possible contingency. Rather than undertaking a single, repetitive task, so-called smart technologies rely on troves of data, often unstructured. These new, vast data sets draw on conventional sources (e.g., consumer purchases), as well as increasingly pervasive forms of internet tracking and trawling. The latter include new technologies that enable data gathering through apps and sensors embedded in phones, wearables, and other objects as well as autonomous or remote-operated mobile devices. Learning algorithms can identify patterns in data imperceptible to humans, often with limited human involvement or direction.[1]

New forms of algorithmic learning technologies alter the terrain of previous debates over substitution versus scale effects, and if, when, and how technologies will be used to complement and enhance workers' skills rather than to devalue them. Technologies like these allow for self-driving trucks that Viscelli (in this forum) predicts will soon have real, direct implications for an occupation that once provided a stable living to those without a college degree. Likewise, similar types of technology may allow for robots' safe traversal of hospital hallways or grocery store aisles. Advances in algorithmic processes have already enabled other types of new and transformative technologies in the workplace such as automated hiring and scheduling, and unprecedented forms of micro-monitoring and task direction in warehouses, home care, food delivery, and more.

The future consequences of the current wave of technological change are not prewritten. That is why we need field-based research at the industry, firm, and workplace level. From there, we can begin to understand how and why employers respond to new technologies and how their decisions affect workers and employment relations.

Cross-Cutting Themes

Several themes emerge from the five industry studies in this forum. First, employers may want to "automate away" their payrolls, but concerns over the outright disappearance of large swaths of jobs prove unfounded. Employers may succeed in reducing head count for specific occupations and market segments within each industry, such as long-haul truck drivers

[1]For a fuller accounting of emerging technologies economy-wide and their implications for policymaking, see Bailey (2022).

and orderlies, dietary clerks, and laundry workers in hospitals. However, in many cases, scale effects arising from increased product or service demand will offset these technologically facilitated substitution effects. Hospital administrators and warehouse operators have found themselves running on a labor market treadmill, unable to hire fast enough to keep up with demand growth. Moreover, aggregate demand growth projections provide employers little hope for relief any time soon. Even in trucking, where company owners eagerly anticipate the seemingly near-term prospects for self-driving technology, job growth will offset much if not all of tech-related job losses as demand from e-commerce accelerates and reliance on workers for non-driving tasks continues.

Second, even where employers appear to be *automating* per se, that is, replacing workers with machines for specific tasks, they are often really replacing one worker for another. When employers implement cashierless checkout, for example, they are not automating the tasks of ringing up and bagging groceries. Rather, they are transferring these tasks from the cashier to the customer, and therefore degrading service quality while supposedly boosting productivity. In this case, employers have still managed to shrink the overall number of cashier jobs, but in other situations, their technology-enabled task redistribution creates new types of tasks for workers. Thus, their actions induce both scale and job-content effects. Consider online ordering for grocery delivery or pickup, which took off during the first months of the pandemic and has continued at elevated levels compared to pre-pandemic days. When customers use a web-based ordering interface to shop for groceries online, employers no longer need labor to ring up purchases or accept payments. They do, however, need workers to collect the purchased items from store or warehouse shelves and deliver them to a customer's car or home. Not long ago, customers had no choice but to do these tasks themselves.

While our studies present a comparatively optimistic outlook with regard to technology's near-term effects on the aggregate number of jobs in each industry, they caution that workers face serious challenges related to technology's effects on their wages and job quality. For instance, employers rely on technology to move work in and out of their own organizations. Such shifts like those we see in food delivery and warehousing threaten workers' job quality in important ways. Tech-enabled changes in production processes and task distribution may allow employers with unionized employees to outsource work to non-union employers, who pay lower wages. Or, the third party may engage workers as (possibly misclassified) independent contractors rather than as employees, denying them even the most basic employment rights, benefits, and legal protections.

Moreover, advances in data collection and algorithmic technologies provide employers with a menu of new approaches to nearly every employment-related function, including hiring, scheduling, task direction, monitoring, evaluation, and discipline or dismissal. Employers across industries often deploy these technologies in ways that intensify work, especially (but not exclusively) for workers at the lower end of the pay scale. This development stands in stark contrast to what many 20th-century commentators and scholars, including John Maynard Keynes ([1930] 1932), predicted. They expected technology would relieve workers of drudgery and reduce their need to work altogether. Across the industries we studied, however, we found examples of employers implementing electronic monitoring and management in ways that increase surveillance and control over workers, and in turn, job-related stress. In the health care sector, home care agencies use electronic visit verification (EVV) to manage and monitor direct care workers through a smartphone. As a result, workers report feeling increased stress from micromanagement, constant surveillance, and invasion of their privacy. Warehouse workers and app-based food delivery workers and truck drivers have also reported that constant location-tracking and other forms of electronic monitoring, plus algorithmically generated metrics that intensify workload and time pressure, have added to the mental and physical stress of their jobs and increased the potential for accidents and injuries.

We initiated these studies and carried out most of the research prior to the pandemic. The circumstances of COVID-19 have undoubtedly altered the course of technological change in certain ways—speeding it up in some cases, slowing it down in others, or redirecting an industry's course. Interestingly, our studies show that many trends that others have attributed to COVID had really been in the works for some time. COVID may have intensified the speed, pressure, and labor scarcity challenges for truck drivers and warehouse workers, but both "shortages" have structural determinants that employers have long tried to address through technological investment. Likewise, the most technologically adept and well-resourced hospitals had already begun to replace laundry workers and food deliverers with semi-autonomous robots that could maneuver hallways to transport drugs, supplies, dirty linens, and even biowaste. However, pandemic-induced demands to redeploy scarce workers and reduce unnecessary worker exposure catalyzed the adoption of robots for these purposes and even led to increased experimentation with cleaning and disinfection robots (Litwin 2020a). COVID also managed to topple institutional constraints to implementing large-scale technological advances, most notably the use of telemedicine.[2] Telehealth had long been up-to-the-task technologically, but skittish payers refused to make it available to patients until the pandemic forced their hand.

Some of these COVID-related shifts point to another important theme that emerges from the industry studies: Employers can implement any given

[2]Just a year into the pandemic, more than 61% of Americans had experienced a televisit medical appointment. Another survey of 50 large health care systems showed that the share of primary care visits conducted virtually shot up from a pre-pandemic level of 5% to a peak of 45%. And, a poll of health care professionals suggested that close to 20% of post-pandemic patient appointments would likely be conducted virtually rather than in person. They may be underestimating, as nearly 90% of patients surveyed elsewhere noted they "want(ed) to continue using telehealth services for non-urgent consultations after COVID-19 had passed." See Litwin (2021).

algorithm or device in numerous ways, including ways that benefit workers. For instance, employers can use technology that limits workers' exposure to dangerous or backbreaking work or that improves their ability to focus on the types of tasks at which humans excel. AI-enhanced exoskeletons, for example, could alleviate truck drivers or warehouse workers of acute strains that arise from heavy lifting (Bogue 2019). Employers could harvest sensor data to anticipate and prevent workplace injuries, or use scheduling algorithms to create staffing schedules that not only align with consumer demand but also incorporate the needs of workers (Lambert 2020). New technology in health care could reduce the time spent on paperwork and redirect attention to patient care.

A broadly path-deterministic, low-road vision of new technologies' effects on the labor market is neither an inevitability nor an accurate depiction of the heterogeneity in markets, institutions, and employers that we find across industries. The industry studies composing this forum collectively show, however, that, absent a stronger role for public policy and worker input, employers' use of new technology will cause harm for many workers, in particular those who are already the most vulnerable to the inequities of our labor markets. In areas with relatively high union density, such as some market segments in trucking, health care, and grocery, collective bargaining can play an important role in ensuring that employers implement technology in ways that also benefit workers. Conversely, where employers have managed to repress unionization or achieve high levels of ownership concentration, workers struggle with little success at realizing potential gains from technological change. Warehousing and retail provide obvious cases in point.

Nevertheless, each author shows how policymakers could carve a purposeful technological change path, one in which product market competition engenders broad-based, measurable improvements in job quality. Consider those workers deployed by third-party apps who have fought to improve their working conditions and to check independent contractor misclassification. Policies prioritizing parity between those working directly for Kroger and those performing the same work for Instacart or Shipt could support these efforts by ensuring that cutthroat competition for the growing online shopping consumer segment occurs not over wages or job quality, but over some other aspect of the service process.

Conclusion

The essays that follow inform our understanding of near-term implications of technological change for work and workers. We trust this work can broaden the focus of research and policy away from a narrow fixation on automation-based job loss and deepen the analysis of the ways in which employers' use of algorithmic technologies threatens workers' wages and job quality. Aside from their substantive import, we hope the essays' inductive approach provides an alternative path to the more dominant, deductive one that has taken hold in predictions about the impact of new technologies.

DIGITAL TECHNOLOGY IMPLEMENTATION IN US RETAIL STORES: TRENDS, POTENTIALS, AND CONTINGENCIES

FRANÇOISE CARRÉ AND CHRIS TILLY*

The retail sector, long a laggard in technology adoption, has in recent years greatly accelerated its implementation of digital technologies. This shift includes pivoting to e-commerce but extends beyond that: As one indicator, in fall 2021 retail was "poised to overtake banking as the top spender on artificial intelligence" (McCormick 2021). Retail's surge in new technology—accelerated since the pandemic—raises urgent questions about the likely impacts on the store-based retail workforce, as part of the broader discussion on the future of work (Autor, Mindell, and Reynolds 2020). Expectations about these impacts vary considerably. Some analysts predict a "retail apocalypse," in which e-commerce will almost entirely wipe out stores (Unglesbee 2020). Others describe an imminent "retail renaissance," in which technology adoption will free workers from repetitive drudgery to serve as expert guides to merchandise and empowered implementers of a store's sales strategy (Renner, Betts, and Cook 2021).

Much is at stake as retail's technologies evolve. Retail employs more than 15 million people (overwhelmingly concentrated in stores), making it one of America's largest employment sectors (US BLS 2021a). Frontline positions over-represent women, young workers, and Latinos (Carré, Tilly, Benner, and Mason 2020). Though overall retail union density in 2020 was a scant 4.6%, grocery stores had much higher density at 16.5% (Unionstats.com 2021). Frontline retail jobs have been of low quality for decades (Carré and Tilly 2017), so it is of vital interest whether digital technology will lead to further degradation, enhancement, or simply disappearance of these jobs.

Our essay for this technology forum is based on our recent research on retail employers' technology adoption strategies and their job impacts (Carré et al. 2020). Drawing on that research, we focus on three main research questions. First, how have retailers used digital investments to transform their core functions over the past few years? Second, based on employers' current strategies, how should we expect technology deployment to evolve over the next five years or so, and what does this mean for the future of stores? And third, and most central, how and to what ends are store-based retailers deploying these technological changes to alter the nature and number of store-based jobs?

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Our findings are principally based on a multi-year study of technology strategies in retail that included 66 interviews of retailers, tech providers, consultants, and worker advocates. In addition, we monitored trade media, and we and co-authors attended nine conferences organized by retail business groups during 2018–2019 (Carré et al. 2020). We build on our previous work (Carré and Tilly 2017, 2020), along with some insights from recent fieldwork (remote interviews and conference and webinar attendance) and trade media and analyst sources.

In brief, store-based retail and its jobs will not disappear with e-commerce's growth. However, the mix of jobs and functions within stores will change, with a large category of jobs (cashiers), mostly held by women, continuing to shrink over the coming years. Changes in job *content* and occupational mix are as important as threats of job declines for store workers. In addition to the possible workload increases triggered by technologically generated opportunities for multitasking and speedups, we single out the risks of worker surveillance and control posed by the deployment of digital technologies designed to track goods and people (customers and workers) in real time.

Retail Context for Technology Adoption

Profiling the Retail Sector and Its Workforce

Retail organizational context and practices vary greatly by merchandise sector, format, and customer segment. Nonetheless, several characteristics of the physical retail environment shape the options that operators face. The industry is "overstored," particularly in its largest segments—general merchandise and grocery stores—and highly price competitive thanks to discounters' influence. These segments have grown increasingly concentrated, with Walmart and Kroger at the top (Carré and Tilly 2017). Over the past 20 years, private equity funds have targeted the sector, finding store real estate a tempting asset; their pressure for returns has intensified pre-existing labor cost-cutting, eroding compensation and job quality and, for some, undermining technology investment (Appelbaum and Batt 2014).

Retail workers receive low pay: Cashiers, salespersons, and stockers all earn 60 to 65% of the median economy-wide hourly wage (US BLS 2021b). Part-time, variable hours and unpredictable schedules prevail (Carré and Tilly 2020).

Discounters' dominance, encouraging customers to shop for low prices, fosters a model based on low compensation coupled with high turnover among frontline workers. Frontline jobs have steadily deteriorated over the past 40 years, degraded by this discounting model but also by the erosion of supporting institutions—the minimum wage, unions—and of the broader social compact that had maintained a floor for compensation and working conditions (Carré and Tilly 2020).

Determinants of Technology Adoption

Our retail findings echo past literature indicating that technology adoption is variable and contingent (Orlikowski and Barley 2001; Cascio and Montealegre 2016). The trajectory of implementation in retail differs across specific technologies, by retail subsector, by market segment, and by company. The pace and extent of adoption also has varied based on shifts in overall economic, social, and policy environments. This set of uneven effects will, in turn, determine the deployment of new technologies in retail stores, their impacts on jobs, and consequences for the workforce.

Store-based retail has a remarkably large number of worksites and workers, which makes for a challenging setting in which to consistently implement a technology. As RetailNext CEO Alexei Agratchev explained, for established retailers with "say, . . . 1,000, 3,000 stores, lots of store managers and regional managers have been there 10 years, they're used to a way [of] doing things, and it's hard to introduce a new way of doing things" (Carré et al. 2020: 38)—especially because store managers are frequently overloaded with mandates from headquarters (Carré and Tilly 2017). Often a technology is installed, but not necessarily used.

Digital tech adoption is proving to be a halting, uneven, and unpredictable process for store-based retailers. In recent years, a growing number of vendors have "pitched" a broad array of tech solutions to retailers for their store functions with promises of labor savings or new avenues for business growth. Yet these tech solutions are experimental and appear likely to evolve or even to be rapidly supplanted. Moreover, the growing technological capacities of equipment, software, and AI applications are outpacing strategy development in many companies.

Retailers' Adoption of Digital Technologies and Job Outcomes

In retail, as in many other sectors, particular digital technologies have been applied to multiple functions, and particular functions have been reshaped by multiple technologies. Here we examine four technology applications especially influential in altering retail processes and affecting job contents and working conditions (see Carré et al. 2020 for other applications). But first, we briefly address predictions of a "retail apocalypse."

No Apocalypse: Stores and Their Workers Will Continue to Matter

Overall, the deployment of digital technologies in retail alters job content and raises questions about job quality. But it does not automatically signify wholesale job destruction as of yet.

Recent trends in retail employment are bifurcated. There have been significant losses in store counts and employment in apparel and department stores, accelerated by the pandemic (US BLS 2021a). Department stores already had hemorrhaged 680,000 jobs from 2000–2019, then lost another

34,000 between December 2019 and September 2021. Clothing stores added a minuscule 15,000 jobs from 2000–2019, only to lose 150,000 after 2019.

Conversely, grocery stores and big-box formats have grown (with supermarkets gaining market share from restaurants). Grocery employment expanded by 100,000 during 2000–2019 and surged 34,000 in 2020–2021. Jobs at general merchandise stores, excluding department stores (a category dominated by big-box merchants), rocketed up 890,000 during 2000–2019 and have added another 105,000 since. "Budget" store formats (dollar stores, deep discounters) have boomed since the 2008 Great Recession.

The bulk of shopping still occurs in stores: In-store shopping accounted for 63% of total retail spending earlier this year (Deloitte 2021), and retailers expect that percentage to climb again as consumers return to stores. And we see solid reasons for expecting stores and their workforces to survive. Consumers will still need places to consider products in person, whether "showrooming" items before buying online, squeezing the produce, trying on apparel, choosing substitutes for unavailable items, or getting a sense of what's available, which search engines cannot fully provide. They may seek social interaction or may need shopping advice that is more personalized and context-sensitive than an artificial intelligence–based chatbot can offer. Furthermore, even "contactless" formats, such as Amazon Go stores, require workers to manage processes and address non-routine customer needs.

Stores also will continue to matter for retailers. In a store, retailers can interact with customers in a rich and multidimensional way, allowing them to upsell and build brand loyalty. In addition, stores are laboratories in which retailers observe customers—how they react to and interact with products. New technologies, for better or worse, make it possible to observe customers much more closely than in the past. Importantly, retailers increasingly use stores as widely dispersed mini-warehouses for "forward deployment" of stock to deliver to online customers or hold for curbside pickup.

These advantages of stores matter more in some places and types of stores than in others. The benefits of stores tend to be greater in dynamic urban centers, and less in scattered small towns and/or traditional suburban malls that are the most "overstored" and have been losing retail outlets for years. Apparel shops, department stores, and home goods retailers, which have borne the brunt of recent store closings, likely will continue to be culled in coming years, and sales of standardized goods will continue to shift to online.

Four Salient Technology-Assisted Changes Currently Underway

Several tech-facilitated changes in retail processes and practices, each drawing on a family of technologies, have significant consequences for job content and quality as well as occupational mix. These changes include sustained e-commerce growth, self- or "contactless" checkout, technologies facilitating enhanced sales associates' roles, and heightened monitoring of merchandise and workers.

Continuing E-Commerce Growth, Rapid Adoption of "Click-and-Collect"

Most major retailers had begun to pivot to an "omni-channel" retail trajectory over the past five years; this trend then accelerated with the health crisis. Most salient, the second largest segment of retail, grocery stores, rapidly accelerated deployment of e-commerce options with order fulfillment from stores and/or warehouses coupled with customer pickup and home delivery. Similarly, large general merchandise and home improvement chains (Target, Walmart, Home Depot, Lowes) hastened their curbside pickup implementation.

E-commerce expansion will likely continue to erode the number of workers in the largest categories of frontline work—cashiers and salespeople. Concurrently, however, new store-based activities will trigger job growth. Order fulfillment takes place out of warehouses but also out of stores, particularly for food orders. Curbside pickup or "buy online, pick up in store" (BOPIS)—rather than home delivery—has become an increasingly important fraction of online shopping, offering lower costs for retailers and generally more convenience for shoppers. Core store functions now include order-picking within stores or in proximate, partially automated microfulfillment centers (MFCs, mechanized mini-warehouses typically located within the store footprint) and handoff, with store workers shouldering tasks that customers previously performed.

Zebra Technologies' Suresh Menon estimates that these added functions have "created approximately a 30% increase in store workloads" (RIS 2021). The frequent consequence for store-based workers is an increase in the range of tasks and workload, experienced as speedup. MFCs can reduce the labor involved in order fulfillment, but the most time-consuming functions—picking fresh produce, deli, meat, and fish—are not easily "automatable."

Cashier-less Checkout: Fewer Positions, Different Mix of Tasks

Retailers have experimented with cashier-less checkout—self-checkout with attendant workers for troubleshooting—for more than 20 years. After fits and starts, this option has recently become more attractive to both retailers and customers. Deployment of self-checkouts ratcheted up during 2020–2021 and is consolidating into a dominant pattern, primarily in groceries, general merchandise, and drugstores, the subsectors in which cashiers are numerous.

The newest self-checkout technologies entail customer labor with few or no worker interactions. They include "scan and go" checkout (shoppers scan with their phone or other device while shopping, pay online, and walk out) and the highly publicized Amazon Go–type checkout (cameras and weight sensors track purchases) being explored by a few major chains. Of interest, though tech companies are also striving to automate stocking tasks, that possibility seems years off.

Like e-commerce, cashier-less checkout implies fewer cashiers and salespeople; indeed, even as grocery added 100,000 jobs in 2000–2019, it shed 80,000 cashier jobs (US BLS 2021b). Women, including women of color, have been over-represented in these occupations, which account for a dominant share of store employment. Remaining workers—those monitoring and assisting self-checkout stations, the most common cashier-less technology—face added stress because they troubleshoot at multiple checkout stations and primarily interact with frustrated customers.

Enhanced Salesperson Roles

Digital technologies can put tools into workers' hands to deliver customer service more effectively and to address a wider range of queries and other issues. Most often this involves accessing inventory data, customer details, past purchases, and product information using mobile devices connected to better integrated company and store data systems. Technologies also can facilitate coordination with store colleagues.

In higher-end stores, the ambition—and cutting edge—is to offer instant access to information about customer purchases, and other characteristics they have communicated, to facilitate "customization" of product offers. Virtual or augmented reality systems play a role, for example, enabling customers to "see" how a particular makeup shade or shirt color might suit them. Interaction may take place in-store or online between a store-based worker and a remote customer.

These role enhancements can be welcome in making the job more varied. But they also come with the potential for speedup created by multitasking. The availability of tools to address multiple situations and requests comes with the responsibility to address all of them, on the customer's time frame expectations—and therefore that of supervisors.

Increased Worker Surveillance and Control

The changes above bring a sometimes explicit but often tacit potential for retailers to increase worker surveillance and control. Data collection about customers is an explicit goal to support merchandising, marketing, and customization (as well as control of in-store theft). Many of the in-store tools used for customer observation and data collection, however, can also observe workers, especially if they are equipped with "wearables" or with company-provided mobile devices.

Surveillance techs of varied types are already deployed. For example, Walmart's "missed scan" technology, using "computer vision" (AI-based analysis of camera images), monitors not only self-checkout stations for theft but also staffed registers to track worker activities; varied sensors for customer movements can also note worker movements; phone location sensors used to track customer trips through the store can also be deployed to track worker phones. Task management software that involves information sharing or verification of task performance (e.g., photos of completed stocking)—all supportive of job effectiveness—can pace the worker. Some applications also include "gamification" features to incentivize faster work.

Automated processes directing work, for example, shelf-scanning cameras that can prompt stockers to fill gaps (thus sparing them the tedious search for gaps), can also prompt them to refill stock more frequently than if they organize the work themselves and address several gaps at once. In more technologically advanced settings, the capacity exists for automated decision-making, for example, scheduling or evaluation of task performance. Amazon warehouses' automated discipline and firing looms large in this field; it could well spread to the management of frontline retail workers, particularly in large chains. This technology would thin out the ranks of frontline supervisors and managers.

Though new technologies bring the capacity to accumulate granular data, the analytics are challenging because they must be tethered to revised strategic goals—which few retailers have yet clearly formulated—and measurable steps toward those goals. According to many industry observers, retailers are not yet able to make use of much of these data. We anticipate this will take time, with data collection underway all the while. Our preliminary assessment is that, by default, the temptation will be to surveil workers' performance and behavior.

Toward a Middle-Term Scenario for Frontline Store Workers

Changes in retail operations already set in motion before 2020 will shape store-based jobs in the next several years. E-commerce will continue to trend upward, accompanied by click-and-collect and by store-based fulfillment tasks, although with the caveat that the cost of the latter also prompts interest in automation. Likewise, various forms of self-checkout will grow, with concomitant loss of cashier and salesperson jobs. The pandemic boosted customer acceptance of these solutions, and retailers have continued to drive that acceptance by thinning the staffing of conventional cash registers.

Similarly, the leading edge in surveillance—pandemic-era camera observation of social distancing and contact tracing to maintain safety in stores—contributed to normalizing customer and worker monitoring. Such monitoring also demonstrated its value to employers, opening the way for expansion of digital surveillance and pacing.

The dangers of surveillance and automation may already overshadow the early digital technologies' promise of opportunities to end drudgery and improve jobs and customer service. Industry consolidation, the increasing ascendancy of discounting (online and offline), the growing role of private equity, and the long-standing use of labor as the main shock absorber do not bode well for the future trajectory of retail jobs.

Ultimately, retailers' implementation of digital technologies will depend on multiple forces. Set-in-their-ways and often overloaded managers, voice exercised by unions and other worker organizations, and public policies will join customer preferences and economic imperatives in shaping retailers' strategic choices. Research approaches to these processes would do well to combine worker surveys with interviews of direct supervisors and mid-level managers, which are the positions in which the contradictions of implementation programs are most keenly felt.

NEW TECHNOLOGIES OF E-COMMERCE AND THE FUTURE OF WORK IN FOOD RETAIL

CHRIS BENNER AND SARAH MASON*

While e-commerce has been expanding rapidly in the retail sector since the early 2000s, the grocery subsector has been slow to follow suit. A combination of ingrained consumer habits and preferences for selecting their own groceries, along with the technological complexities of handling the myriad products and diverse consumer diets, created significant barriers to expansion in grocery e-commerce. In recent years, however, new technologies and delivery systems have opened up new possibilities. More sophisticated inventory management systems, automated order fulfillment methods, and user-friendly online ordering software, combined with the growth of platform-based delivery services, have contributed to a rapid growth in e-commerce in the grocery sector. Consumers now have a wide range of options available for ordering food to eat at home.

The implication for work and employment in food retail is complex. The most striking shift in labor associated with these technological changes has been an *increase* in jobs, as consumers are paying people to do work they used to do for free themselves. New technological affordances are also contributing to shifting revenue and power relations between various actors in the food retail sector. At the moment these changes are associated with a general deterioration of job quality for workers in the industry, but this trend varies substantially across the industry and is contingent on company strategy and changing consumer preferences. This range of possible strategies and outcomes highlights the importance of more in-depth and subtle

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research on the evolving factors shaping relationships between technological change and work in the food retail sector.

Currently, four major patterns of work and employment seem to be accompanying the growth of technologically enabled e-commerce in food retail. First, a variety of new jobs are being created in online ordering, fulfillment, and delivery, with most of these jobs growing outside of traditional grocery stores. Second, associated with this outsourcing is a general degradation in job quality, in part associated with the growth of platform-based independent contractor employment in delivery, but also with the growth of algorithmic management in fulfillment as well as delivery. Third, these interfirm relationships have led to complex shifts in revenue and power among actors involved in food retail, with smaller firms more reliant on external service providers. Finally, these relationships are also contributing to the blurring of boundaries between types of food retail, such as an increase in the purchase of prepared foods eaten at home and the growth of semi-prepared foods such as meal kits, with associated shifts in work.

E-commerce remains a small portion of overall grocery sales, but if current trends continue, the changes described here will become even more important to shaping work and employment in the industry.

Food Retail Industry Context

Approximately 3.2 million grocery workers, who account for 20% of all retail employees, make grocery the largest employment sector of the retail industry. Although wages vary according to job and region, the average pay for all grocery workers is approximately $15 per hour.[3] This rate is higher than in many retail subsectors, in large part because the grocery sector has a relatively high density of union membership, with approximately 18% of grocery store workers represented by a union in 2021, compared to 5% across the entire retail sector (Hirsch and MacPherson 2003). Unionized grocery workers are represented primarily by the United Food and Commercial Workers (UFCW), the largest private-sector union in the United States. UFCW represents 1.3 million workers, 60% of whom work in grocery.

The grocery industry is dominated by a few large companies. In 2017, Walmart, the industry's largest firm, enjoyed 26% of all sales, followed by Kroger (10%), Albertsons (5%), and Ahold Delhaize (4%) (Brandon Gaille 2018). The grocery sector has become increasingly concentrated over time through a combination of mergers, acquisitions, divestitures, and internal growth. By 2016, the top four players accounted for nearly 45% of total grocery sales. The competitive strategies of these top firms have an important impact on the industry as a whole. At the same time, since grocery stores exist in nearly every community across the country, the grocery industry has

[3]According to the Bureau of Labor Statistics, average pay was $15.36 in 2020 in food and beverage stores. See https://www.bls.gov/oes/current/naics44450A1.htm.

a very "long tail" (Anderson 2008), with a wide diversity of local stores, strong regional firms, and various niche market outlets.

New Technologies of E-commerce

Prior to the pandemic in 2019, e-commerce in the retail sector overall had risen to 10.7% of total sales with annual growth rates of 14%. In the grocery subsector, however, e-commerce remained only 1.1% of total sales with a growth rate of 4% (US Census Bureau 2021). The pandemic has contributed to a rapid growth in online sales, with some estimates as high as 14% as of November 2021 (Brick Meets Click 2021).

To understand the implications of these changes, it is valuable to recognize that e-commerce actually involves three distinct steps, each with its own technological infrastructures. First is ordering and payment. Customers put items into a digital shopping cart and pay online. Online ordering systems are reliant on an integrated, top-to-bottom website and increasingly sophisticated user-interface systems, including visual design elements, functional interactivity, and means through which a user can interact with the ordering system (e.g., mobile, voice recognition, and so on). New developments in back-end data systems also are important. The vast collection of data enabled by online ordering systems and their machine-learning components may be used by stores to glean better customer insights, which in turn can lead to price optimization programs or dynamic pricing, sophisticated promotion targeting and customer loyalty programs, assortment planning (product selection to maximize sales and profits for a specified time), and personalized in-store marketing. Given the complexity involved in pricing thousands of items in rapidly changing market conditions, the insights from these dynamic modeling systems can have a major impact on pricing and promotion strategies, inventory, and customer satisfaction (Bain & Company 2018).

The second step is fulfillment. At the moment, fulfillment by hand from existing grocery stores is the most common approach, but also the most inefficient, as existing grocery aisles and shelves are not optimized for rapid order fulfillment. Companies are trying to address this by developing fulfillment software that can better integrate store planograms and incorporate real-time, in-store inventory with mobile device guidance systems. These systems provide direction to order pickers, allowing them to fulfill multiple orders at once and increase the efficiency of these in-store picking and packing processes. Alternatively, some grocery chains are pursuing more automated fulfillment systems, relying on a combination of robot technology and artificial intelligence to bring items to pickers, who then pack orders for delivery. These systems are typically divided into "micro-fulfillment centers," which can be used for the most commonly ordered online goods and typically do not include frozen items, or larger-scale centralized fulfillment centers typified by the UK food retailer Ocado, which can handle all inventory items.

The final step is delivery to the customer. Customers pick up their order at the grocery store, or drivers deliver the groceries to customers' homes. A number of automated, autonomous vehicle delivery systems are in the early stages of deployment. Whether done autonomously or by human hand, the home delivery of perishable groceries often is constrained by customers needing to be home to receive their orders. In an attempt to address this barrier, a number of companies including Walmart and Amazon are exploring smart-lock systems, allowing pre-approved delivery drivers to enter a locked premise with an access code and enabling them to put perishable items in the refrigerator (Dean 2019; Forde 2019).

Implications for Work and Employment

Creation of New Jobs

In contrast to many of the predictions that technological change would lead to large-scale job loss, in grocery retail the growth of e-commerce is creating new jobs. The most visible of these new jobs are in delivery, with the vast majority of delivery workers classified by third-party platforms as independent contractors. Some companies, such as Instacart, hire people to perform order fulfillment as well as delivery, and prepared food delivery companies, such as Door Dash and Grubhub, are also now getting into grocery delivery. New positions are also being created in order fulfillment. At the moment, the vast majority of these are grocery store employees fulfilling orders from existing grocery store shelves, though employment in dedicated semi-autonomous fulfillment centers is increasing. But some workers are employed by third-party platform companies to fulfill orders as well. Finally, the creation and management of online ordering systems require skilled technical positions. Larger grocery firms such as Walmart and Kroger have substantial technical personnel in-house, but many grocery firms use outside contractors or third-party systems such as Instacart for these services.

Eroding Job Quality

Significant concerns are surfacing about the quality of these newly created jobs. Even in the technical positions, which pay above average for the grocery industry, workers in the grocery industry are paid less than their counterparts in other industries. The greatest area of concern, however, is in delivery jobs. Some delivery workers are employed directly by grocery firms as regular W-2 employees, with pay estimated at $17 to $18 per hour, depending on location.[4] Most grocery stores, however, are using third-party delivery services, most prominently Instacart and Shipt. Here, as a variety of studies have shown, workers face low pay, lack of access to employment protections and benefits, and insecure earnings (Griesbach, Reich, Elliott-Negri, and

[4]See https://www.glassdoor.com/Salaries/grocery-delivery-driver-salary-SRCH_KO0,23.htm.

Milkman 2019; Benner 2020; Benner, Mason, Carré, and Tilly 2020). They also are highly vulnerable to algorithms—a form of surveillance—that can lead to seemingly arbitrary punishments and high stress. All food delivery platforms use algorithms to manage work, such as assigning jobs, evaluating performance, assigning payment, and structuring deliveries. One key concern here has been how apps treat tips provided by customers. Door Dash, Instacart, and Shipt all have received substantial negative publicity for deducting customer tips from the delivery payment to drivers, rather than adding it to the drivers' pay. Customers think they are providing a tip to the driver, but in fact their tips provide nothing additional to the drivers and instead simply subsidize the companies' delivery costs. Evidence suggests that Instacart has a particularly troubling set of practices with their algorithms. Some research shows startling evidence of Instacart providing more stringent regulation of the time and activities of workers than other platform delivery companies, in what the authors call "algorithmic despotism" (Griesbach et al. 2019).

Outsourcing of Jobs

With all of these new components of the industry—online ordering, order fulfillment, and delivery to customer—where revenue is captured in the food retail sector is shifting, with implications for workers' livelihoods. Traditional grocery stores have the option of keeping each of those functions in-house, or outsourcing some or all of them, with in-house jobs typically providing better pay and benefits. For many of the smaller chains, who lack their own online ordering and delivery systems, partnering with Instacart was seen as a means to jump into new e-commerce opportunities quickly, especially in the face of Amazon's 2017 purchase of Whole Foods. For larger chains, including Walmart, Albertsons, Kroger, and Ahold Delhaize, which already had online ordering systems, partnering with Instacart could bring cost-savings advantages, particularly with Instacart's use of independent contractors lowering labor costs. With these partnerships, however, concern is growing that customer loyalty may be in jeopardy, as consumers primarily interact with the third-party service rather than the grocers themselves. Additionally, Instacart now has access to millions of customers' data. Access to these data may give Instacart access to supplier advertising dollars and potentially increase direct-to-consumer sales from suppliers. As a result, many retailers are seeking ways to reduce or eliminate their reliance on the third-party company (Ladd 2019).

New Food at Home Channels with Low-Quality Jobs

Overall growth in the grocery industry is in part dependent on how much of consumers' overall food dollars are spent on food consumed at home. Here, the grocery industry has been losing market share to the restaurant and fast-food industry for decades. For example, food consumed at home accounted for only 45% of total food expenditures in 2019, down from 53% in 1999.[5] This trend poses a formidable challenge to grocery stores struggling to outcompete the convenience offered by prepared meals.

In addition to this trend, the boundaries between groceries and food consumed away from home are blurring. Grocery stores, in an attempt to offer the ease and convenience of restaurant-prepared meals, are developing and expanding full-service delicatessens and an assortment of prepared meal items. Meanwhile, restaurants are experimenting with expanded delivery options, making it easier to have fully prepared meals delivered directly to the home. The growth of third-party delivery platforms means that entire categories of restaurants that never used to provide delivery—from fast-food to white-table restaurants—are now providing home delivery. In addition, so-called ghost kitchens—restaurants that produce food solely for delivery without any physical retail presence—have emerged.

Finally, subscription meal-kit offerings from companies such as Blue Apron, Plated, and Home Chef are becoming more widespread. Meal kits also can be purchased in a grocery store; major grocery chains have purchased meal-kit companies (Home Chef for Kroger, Plated for Albertsons) to expand their offerings in this product line. Full meal kits that customers cook themselves are in many ways a simple evolution of similar offerings that grocery stores have stocked—everything from baking kits, to premarinated meats, to full frozen meals.

The implications of these trends for job quality are complex, but generally not good. Widespread evidence suggests that jobs in most restaurants typically have lower pay, fewer benefits, and more part-time work than do grocery store jobs. Research on ghost kitchens and meal-kit fulfillment centers is much more limited, but evidence shows that workers in these sectors struggle with low wages, unpredictable schedules, and workplace-related injuries (Thomason, Sanchez, and Valdivia 2018).

Future Trends

The proliferation of new options that consumers now have at their fingertips for acquiring food for in-home eating is creating significant challenges for grocery companies. E-commerce trends in food retail continue to evolve rapidly, with new technologies in semi-autonomous fulfillment centers in particular ramping up. Firms are now experimenting with new offerings, partnerships, and strategies for meeting this new technologically enabled food landscape. With conditions continuing to shift, it is difficult to make predictions about where these trends will lead. But as grocery stores have tried to respond, there appears to be a growing polarization in the industry. Some chains are developing more prepared food and semi-prepared food options, creating new

[5]USDA Food expenditure data, May 2021 update. See https://www.ers.usda.gov/data-products/food-expenditure-series/.

opportunities for more value-added products and potentially retaining more highly paid workers. But the low-cost, discount chain sector of the industry also seems to be expanding rapidly, putting price pressures on more traditional grocery stores, which is likely contributing to further erosion of wages and working conditions. E-commerce will hold a minority of total revenue in food retail for the foreseeable future, but it has clearly become a substantial portion of the industry with potential for continued growth. Understanding the implications of these trends for workers will require careful attention to shifting inter-firm boundaries, dynamics of paid and unpaid labor, and complex power relations between firms, and between workers and employers.

TECHNOLOGICAL CHANGE ON THE FRONTLINES OF HEALTH CARE DELIVERY

ADAM SETH LITWIN*

Technological advances in health care have long helped clinicians extend and save lives, increasing the quality of care and the level of comfort they can provide their patients. But, do today's emergent technologies, predicated on digitalization and artificial intelligence (AI), have a qualitatively distinct impact on the quality of care and the efficiency with which providers deliver it? Likewise, how are these advances changing work and labor market outcomes for those frontline workers tasked with care delivery?

While technology's potential impact on care quality would be enough to warrant researchers' attention, the sector's singular macroeconomic and political status places it center stage in the realm of public policy. Citizens quite reasonably demand it function smoothly and efficiently, as taxpayers foot about half of the nation's annual health care bill while payers and providers benefit from favorable tax policies. By any measure, demand for health care will grow for the foreseeable future, guaranteeing health care spending will, too. National health spending will grow at an average annualized rate of 5.5% per year over the next 10 years, reaching nearly $6.0 trillion by 2027, according to the Centers for Medicare and Medicaid Services

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(CMS). That is 0.8 percentage points faster than GDP and implies health care's share of total production will increase from 17.9% to 19.4%.[6]

On the "supply" side of the ledger, health care and its associated occupations are expected to account for 40% of the 8.9 million new jobs created over the next decade, increasing the sector's share of overall employment from 12.4% in 2018 to 13.8% in 2028. So, much more concerning than technology's implications for job *loss* should be its potential impact on job *quality*.

The findings I present here emerge from more than a decade of on-the-ground research in the health care sector (e.g., Eaton, Konitsney, Litwin, and Vanderhorst 2011; Litwin 2011; Litwin, Avgar, and Becker 2017) in addition to 32 interviews conducted expressly for the underlying research report on which this short essay is based.[7] All interviews were conducted either in-person or by phone/internet between April 2018 and June 2019. Interviewees included hospital and home health agency administrators, union representatives, health care IT experts and consultants, and technology developers. I also attended health care conferences and trade shows targeted mainly at would-be investors, where I had a dozen less formal but equally informative conversations with those operating in the frontline health care technology space. Government data sources also fed my analysis.

A Sector Like No Other

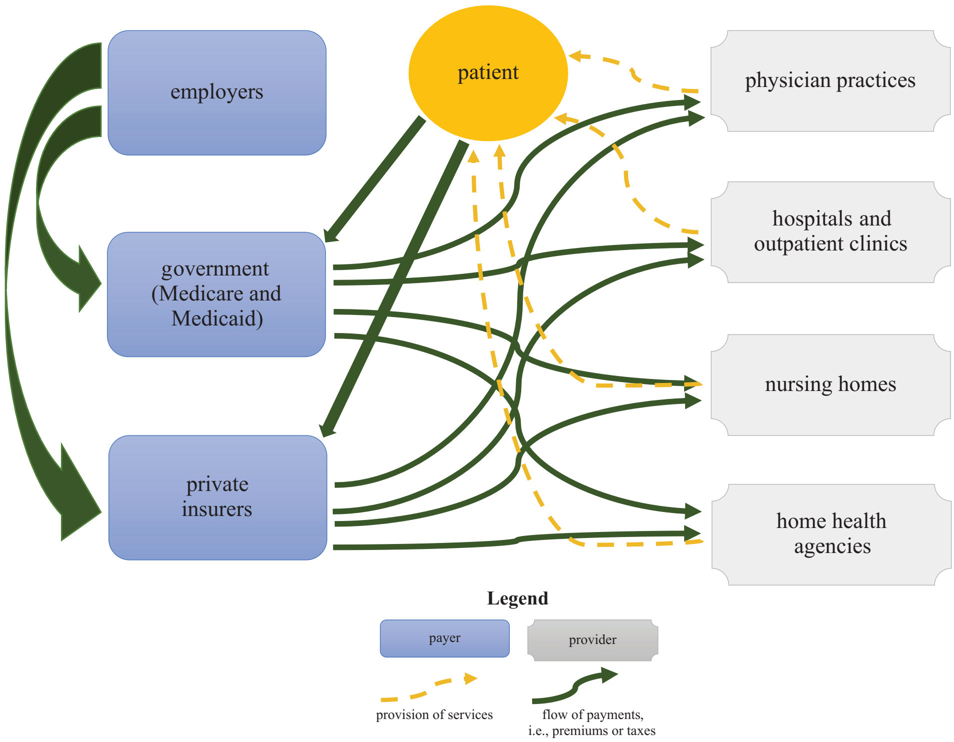
Understanding the drivers of technological change first requires that one grasp the peculiar structure of the sector and the incentives facing medical practices, hospitals, and the other organizations that employ care providers. And, this structure—namely, one that separates the financing of care from its delivery—yields some socially inefficient and inauspicious outcomes. For example, the delayed and lumbering transition from paper-based to electronic health records (EHRs) arose from providers' systematic underinvestment in new systems, easily explained by the likelihood they would absorb the full costs of digitization but not the benefits. This same logic extends to most other technological innovations in frontline care delivery—with similar results of slow adoption of technologies that would benefit patients.

Figure 1 helps explain why. It provides a simplified representation of the US health care system. Traditionally, providers followed the fee-for-service (FFS) model, in which the insurer (commercial and/or government via Medicare or Medicaid) pays the provider for each service after it is delivered, based on a predetermined rate. The provider then pockets the difference between what it collects from the payer (plus co-payments or co-insurance from the patient) and the cost of providing the care. Left to market forces alone, provider organizations would invest in technologies

[6]When not cited otherwise, all facts, figures, and their original sourcing, where applicable, can be found in Litwin (2020b).

[7]I encourage interested readers to consult Litwin (2020b), freely accessible on the web.

Figure 1. Simplified Map of the US Health Care System



that increase efficiency—that is, patient throughput and the number of services for which they can bill the insurer. They would *not* invest in technologies that reduce the number of services for which they can bill, even if that reduction arises from keeping patients healthy.

Alternatively, in value-based care (VBC) systems, particularly promoted under the Affordable Care Act of 2010, insurers contract to reimburse providers on a per-member-per-month basis. Under this model, the provider internalizes the risk of its patient population and has incentives to keep patients healthy and out of hospitals or emergency rooms. The provider must finance all necessary care from the capitated payment, leaving the residual revenue as its profit. Under this model, provider organizations have incentives to invest more in technologies that improve care quality because they will capture more of the benefits. All health plans marketed today contain at least some features of VBC, but FFS remains the dominant payment model. The net effect of the two models is that more providers have incentives to invest in efficiency-enhancing technologies (under the FFS model) than in quality-enhancing technologies (under the VBC model).

The Context for Technological Investment

Aside from directly influencing providers' incentives to adopt new technologies, payment models constrain the behavior of provider organizations as employers. Historically, the FFS model left providers flush with cash, as plans placed few limits on the number and nature of claims providers could submit to insurers. However, payers no longer issue FFS providers a blank check, accepting any claim at any rate providers demand. Likewise, the VBC model forces providers to be cost conscious, as the amount of monthly revenue is essentially fixed.

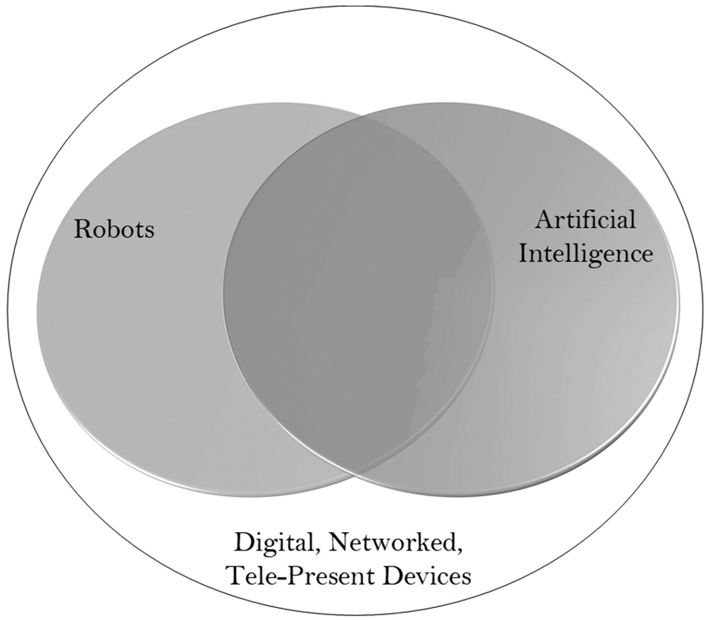
Provider organizations have responded to cost pressures chiefly by exploiting economies of scale and scope through consolidation and coordination. And, technological developments have both facilitated and themselves been hastened by this restructuring. Consolidation typically has taken the form of a "horizontal" merger of two to three community hospitals, sometimes under the umbrella of a large hospital chain. Aside from creating more opportunities for hospitals to leverage scale economies, including the purchase of expensive, fixed-cost-intensive technologies, these mergers imbue providers with more bargaining power vis-à-vis the insurers with whom they must negotiate.

Employers increase the scope of their provider organizations by gathering as many services under their corporate umbrella as possible. A single health care provider organization can coordinate across one or more hospitals, a host of primary care and specialist physician medical offices, outpatient care or surgical centers, skilled nursing facilities, and home health agencies. Doing so facilitates transitions from one care setting to another and should improve coordination of care more broadly. Under FFS, consolidation also allows for lucrative, intra-organizational referrals. Under VBC, this coordination can further deliver the sorts of cost reductions and quality improvements that create value that providers can actually appropriate. For example, economies of scope arise when providers can help patients stave off unpleasant and costly chronic diseases—including diabetes and congestive heart failure—that afflict 60% of American adults. However, capturing this value calls for more upfront monitoring, health coaching, and patient education. Like prevention, disease management similarly requires that patients be guided, reminding them to take their medication, to pick up their prescription refills, and so on, and, more broadly, to engage in health-enhancing behaviors. Changing demographics—namely, increasing life expectancies and the onslaught of aging "baby boomers"—will only intensify the rewards to those provider organizations that successfully manage if not prevent chronic disease in the patients they serve. And, provider organizations are keen to adopt technologies that will aid them in these efforts.

Employers' Favored Technologies in Frontline Care Delivery

As provider organizations strive to consolidate and coordinate their way to increased profitability, they turn to digital technologies networked to the web, the cloud, and one another. Figure 2 shows the three "families" into which we can sort these technologies. Note the nature of the relationships between categories. While we consider members of all three groups to be

Figure 2. Emerging Technologies in Frontline Health Care Delivery



digital and networked, only some maintain the sort of physical presence that allows them to grasp objects and perhaps even to move, transform, or rearrange them, for instance, robots. Other technologies are imbued with AI, enabling them to recognize and respond to external prompts and to environmental cues more broadly.

Devices: Digital, Networked, and Tele-Present

The "supercategory" in Figure 2 refers to a set of technologies so ubiquitous and expansive that it almost defies labeling. Smartphones and tablets serve as the most obvious physical manifestations of this information technology (IT), though the number of devices that can be networked or "smartened" knows no bounds. Likewise, the suddenly commonplace example of a technologically mediated tele-visit—in which a home-based patient consults and interacts with a remotely located provider—should be one many readers have now experienced personally. But, the telepresence enabled by digital, networked devices has many other applications, some of which debuted before the pandemic. For example, Kaiser Permanente, the largest health maintenance organization in the country, has experimented with hybrid visits, in which a licensed practical nurse on-site at the patient's home assists a remotely located physician in the provision of postoperative care and treatment for wounds and minor burns.

Hospitals have also begun to extend their reach through telepresence. Mercy Virtual Care Center (MVCC), a "virtual hospital" in suburban St.

Louis, provides specialist care remotely through a hospital-at-home model, whereby providers at MVCC can check vital signs, record notes, respond to alarms, issue orders, undertake exams, and talk with patients. Providers can even track patients with wireless devices, getting pinged if a sensor detects a fall or a sudden change in blood pressure or body temperature. MVCC also offers virtual care to patients who have been admitted to conventional hospitals' intensive care units (ICUs). These smaller hospitals are generally within MVCC's network but often are located in distant, rural areas. In this case, physicians and nurses based at MVCC monitor patients and digest vast streams of data generated through the conventional hospital's EHR system, freeing up on-site providers to connect personally with patients.

In the home care subsector, the most talked-about and most widely adopted application of digital, networked technology has been electronic visit verification (EVV). EVV allows home care agencies to track and verify the labor provided by caregivers to Medicaid recipients and their families, essentially serving as a way for direct care workers to clock in and clock out. Through an app installed on their own smartphone or through a dedicated device provided to them, home health and personal care aids can maintain and manage their schedules, and their employers can track their progress in real time. On its face, EVV is intended to ensure that when a caregiver bills for services, he or she actually has provided them. As a result, lawmakers aiming to thwart fraud against those receiving care and those funding it—taxpayers—have essentially mandated the use of EVV by making Medicaid payments dependent on its use. As with any online service, however, punching in and out digitally allows for the collection of location information and all sorts of additional data as well as opportunities for micromanagement.

Robots

Unlike their imprecise, dangerous, and usually caged industrial ancestors, today's workplace robots are a subcategory of the tele-present technologies just discussed. (See Figure 2.) Aside from being connected to the web or the cloud, they are agile, sensitive to their surroundings, and much less dangerous to co-workers, at least in a physical sense, than earlier iterations. More important, modern service robots can undertake far more than a static, predetermined sequence of movements and other actions. Many instead operate semi-autonomously—accepting external commands from users as well as maneuvering and operating on their own by taking in, processing, and reacting to information absorbed through sensors.

In the hallways of technologically inclined hospitals, in addition to navigating providers and patients, one will encounter these robots in the form of "smart carts" that deliver meals and pick up dirty trays, deliver clean linens and take away the soiled ones, pick up and remove rubbish as well as hazardous medical waste, deliver clean medical supplies, and transport prescriptions to nursing stations. They rely on overlapping laser, sonar, and infrared sensors to traverse the halls to their destination while avoiding human and nonhuman obstacles.

Artificial Intelligence

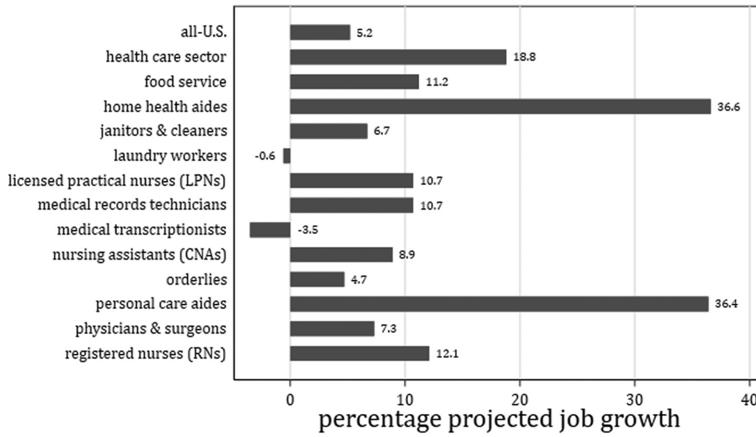
Some of these robots carry another powerful arrow in their e-quiver—AI. As Figure 2 shows, AI need not be seated in a robot in order to be useful in frontline care delivery. However, its application in frontline care delivery is predicated on its attachment to the cloud, the only way it can tap the vast amounts of data required to power its algorithms. What makes AI so useful is its ability to "learn" by crunching or absorbing enormous quantities of information and data—a particular form of AI called "machine learning" (ML). Increasingly, AI also can process unstructured textual or spoken inputs, using natural language processing (NLP). NLP translates free text into standardized or structured data.

Advances in AI will boost access to care through professionally mediated clinical decision support (CDS) systems. CDS systems link health or patient observations with health knowledge to influence health choices by clinicians for improved health care (Healthcare Information and Management Systems Society 2010). They have long been embedded in most EHR systems; however, prior to the advent and incorporation of AI into these systems, all of the rules and their associated alerts needed to be manually entered into the system explicitly and regularly updated. With ML, software now can import and analyze massive accumulations of historical patient data in the context of established best practices and cutting-edge, peer-reviewed research to generate its own decision rules.

Implications for Work and Workers

In the absence of countervailing power, managers and administrators of health care–providing organizations will try to "automate away" as much of their payroll as possible. If this strategy were actually feasible, then one could expect massive job loss to result from advances in health care technology. And, given the overrepresentation of women and African Americans in the health care labor force, it would hit these groups especially hard. If history is any guide, however, employers will find that such "technology-alone" strategies will not pan out (Kochan, Eaton, McKersie, and Adler 2009; Litwin 2011; Nachman 2021). Employers will clearly need actual workers to effectuate their plans to profit from care coordination, in particular the prevention and management of chronic diseases. As they slowly realize this and as they adjust to more realistic forms of work restructuring, their attention should shift, as researchers' has, from concerns over job loss to the aforementioned focus on the quality of all those jobs remaining, and a mass of newly created ones. The Bureau of Labor Statistics (BLS) predicts job growth of nearly 18.8% in health care relative to an economy-wide projection of 5.2%. As Figure 3 shows, the largest projected job growth is

Figure 3. Employment Projections for Selected Occupations



Source: US Bureau of Labor Statistics (2019).

Notes: The all-U.S. category incorporates every sector of the economy. The health care sector includes 2017 Census industry codes 7290–8290, inclusive. The definitions of each of these industries appear in the appendix of Litwin (2020b). The health care sector excludes social assistance. For the individual occupations aside from food service, I consider only those working in the same set of 4-digit industries. Food service captures the Food Preparation and Serving-Related Occupations major occupational Standard Occupational Classification (SOC).

estimated for home health aides (36.6% projected job growth), personal care aides (36.4%), and RNs (12.1%)—the last of which is actually the highest paid and most unionized job class analyzed.

Unfortunately, both of the direct care job categories that are anticipating sizable increases in demand pay poorly and require, at most, a high school education. Interestingly, demand for laundry workers in the sector is projected to fall, despite the fact that across-the-board demand for these workers (not shown in the figure) is expected to increase slightly. Medical transcriptionists are the only other occupation we analyze showing negative projected growth over the 10-year time horizon. Although speech recognition technology could be a future driver of job decay for this occupation, these numbers probably stem from the transition from paper-based health records to EHRs, into which most practitioners simply enter patient data directly. Notwithstanding, the information in Figure 3 provides even more justification for policymakers to shift their attention from mitigating job loss to ensuring job quality.

Technology, aside from raising concerns about job quality, could actually be a real engine for its amelioration. Networked, digital devices, perhaps powered by AI, will serve as tools to provide all of these frontline workers with information and data. Admittedly, many of these workers cannot yet independently, autonomously, and reliably act upon the amassed information to treat patients. Home health aides and certified nursing assistants (CNAs), for example, certainly cannot yet assume the high value-added work of registered nurses (RNs). The promise of technology, however, suggests that employers' investments in skills-upgrading could well enhance efficiency.

Consider the use of robots for the dietary services function of a large hospital. They could and perhaps should assume the arduous work of transporting food and then dirty dishes and trays up and down long corridors. As one developer told me, this would allow dietary workers to "spend more time helping patients get the ketchup packet opened." Glibness and disingenuousness aside, he correctly noted that service robots do not provide compassionate care in the same way humans can. And, assuming he and his employers-cum-customers endeavor to do more than reduce headcount—their typical and instinctive goal, as I noted above—one can identify constructive ways that technology can elevate otherwise-displaced workers.

For example, dietary clerks who cede their delivery responsibilities to robots could spend more time educating patients on dietary alternatives, thereby serving their employers' care quality goals in ways robots cannot. In the increasingly competitive landscape for inpatient care, patient perceptions of genuine empathy contribute materially to hospital performance metrics. Similarly, orderlies devote large swaths of their time to transporting supplies around the hospital. Were robots to assume this work, orderlies could leverage their unique ability to interact with patients as well as their knowledge of the facility and the campus to transport and set up new telehealth carts and to prepare patients for their telehealth interactions.

In both cases, the job content effects would increase the quality of this work as well as the job security of those undertaking it. Moreover, pay certainly falls under the rubric of job quality. And, to the extent new complementarities between human and technological capital occasion increases in marginal productivity—as they do for these two simple examples—benefits should redound to workers in the form of pay increases. The impact on orderlies would assuredly be welfare-enhancing, as 58% of orderlies are people of color, relative to 36% of the workforce at-large.

Of course, employers will bring such suggestions to fruition only if labor market exigencies force their hand or if unions can otherwise counter employers' knee-jerk interest in trimming employment rolls. But, employers would be wise to abide. When experienced, frontline workers exit the organization, valuable and often tacit operational knowledge exits with them (Stinchcombe 1990; Adler and Borys 1996). And, empirical research—much of it conducted in health care settings (e.g., Preuss 2003; Litwin 2011; Litwin and Eaton 2018)—makes clear that performance erodes as a result.

Technology could also augment rather than automate the role of supposedly low-skilled home care workers, again disproportionately people of color, and in this case predominantly female and holding only a high school diploma (or less). Instead of relying on EVV that Taylorizes or rationalizes this work, tech-enabled home care workers could take on the role of care coordinator for their patients, relying on their smartphones as a tool for communicating with all of their clients' other providers. After all, home care workers spend more time with the patient than does anyone else on the care team. And, with the proper additional training, they would be best positioned to track patients' well-being and to communicate changes promptly and accordingly. Imbued with AI that could help the home care worker predict falls or sense subtle changes in behavior, both the technology and worker could deliver still more value to every stakeholder than they are presently able to. Applied in this manner, technological advances become part of a self-sustaining, virtuous circle—the very sort that properly encouraged health care employers will have the power to effectuate.

So, how does this all "net out" for a health care workforce experiencing the rapid advance of new technologies? The good news is that both the economic and technological outlooks suggest plenty of jobs in the sector for the foreseeable future. And, one can easily envisage pathways by which technology could bolster otherwise precarious or under-rewarding work. The bad news is that employers—clinics, hospitals, and home care agencies—are unlikely to see on their own, at least initially, the obvious ways technology could augment frontline care delivery work, improving its quality and boosting outcomes for patients, too. Policy can catalyze this realization, essentially steering this fast-moving technological engine down the job-quality high road.

INVESTIGATING IMPACTS OF SELF-DRIVING TECHNOLOGY ON TRUCKING

STEVE VISCELLI*

How many truck drivers will be displaced by self-driving technology? The premise of this question perpetuates a flawed view of how technology develops—one that plagues contemporary debates about the future of work—because it presents technological development as a process of scientists and engineers applying knowledge and technique to the material world to find the "one best way" to perform some task. In fact, the labor process, labor market conditions, and most important, policymakers will shape how self-driving technology will work and what its impacts will be.

Initial research suggested trucking is highly automatable (Frey and Osborne 2017), and newspaper headlines, consultants, and policy experts suggested millions of jobs could soon be eliminated (Center for Global

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Policy Solutions 2017; McKinsey Global Institute 2017; Veryard 2017). More recent analyses modulated these early estimates, concluding the number of jobs at risk to be more limited and the time horizon for adoption further off (Viscelli 2018; Groshen, Helper, MacDuffie, and Carson 2019; Gittleman and Monaco 2020; USDOT 2021).

This essay summarizes research on how variation in work and job quality and policy could shape the development and impact of self-driving trucks. It builds on my long-standing research on trucking, including hundreds of interviews with truckers and six months of fieldwork as a long-haul trucker. Data include primary sources and interviews on the development of self-driving technology. I conducted interviews with more than two dozen executives, engineers, and employees at eight firms developing self-driving technology for trucks.[8] I also conducted more than a dozen field visits to these firms, including demonstration rides in self-driving vehicles. I found that self-driving trucks would transform goods movement, but that policy will determine precisely who wins and loses.

Technology in Trucking

Trucks move a little more than 72% of the freight in the United States. Approximately 1.9 million heavy-duty truck drivers transport goods in the nation. Truckers' work, pay, and schedules are as varied as the freight they move, from potato chips to toxic waste. Unionized truckers and those with the best jobs can earn more than $120,000 a year and be home every night, while new truckers can earn less than minimum wage and live out of a truck for months. Truckers might be paid hourly or just for the miles they drive. In some cases, truckers are classified as independent contractors and are responsible for paying all the costs associated with the truck they drive. Truckers can spend up to 11 hours driving per day (as limited by safety rules), but the job often entails many additional, non-driving duties, including waiting to be dispatched or loaded, fueling and inspecting trucks, handling paperwork and freight, and more.

The trucking industry is divided into segments. The first consideration is whether the goods being moved are produced or sold by the company operating the trucks (a "private" fleet) or by a company that hauls goods for other firms (a "for-hire" fleet). The distance traveled is also important. Less than 150 miles is considered "local," whereas anything beyond that is "long-haul." Then, the size of the shipment is important, ranging from a single parcel to less-than-truckload (LTL) (e.g., moving shipments from a few hundred to 10,000 pounds) to full "truckload." Truckload is further differentiated by trailer type: dry van, refrigerated, flatbed, tank, and so forth. The

[8] I have advised government agencies on self-driving trucks and consulted for self-driving truck programs at Uber ATG and Ike. I am currently a member of the Industry Advisory Council at Aurora Innovation. This research was not funded by any government agency or firm. Public interviews were used whenever possible because many observations and conversations were subject to nondisclosure agreements.

service and economics of each segment determine the job requirements and job quality for workers. In general, private, LTL, and parcel provide "good" jobs—those with security, stable and living wages, and schedule regularity. More competitive segments, such as long-haul, for-hire, truckload, and port trucking, provide jobs of poor quality. Not surprisingly, perhaps, the latter segments experience extremely high worker turnover relative to the former.

Much of the variation in the quality of trucking jobs developed after the Carter administration deregulated the industry with the Motor Carrier Act of 1980. Regulation, begun in 1935, mandated licenses, known as "authorities," to haul certain freight to and from various cities. This model promoted terminal systems that allowed carriers to combine freight of different types from one place, send it over long distances in combined loads, and then break it down at terminals for local delivery. These carriers were typically unionized by the International Brotherhood of Teamsters (IBT), which began aggressively organizing intercity trucking in 1934. By 1964, Jimmy Hoffa, president of the IBT, had established the National Master Freight Agreement, which effectively set the wages and working conditions for truckers across the United States.

Deregulation allowed truckload carriers, which move shipments directly from shipper to receiver, to haul previously regulated freight, resulting in cutthroat service- and labor-market competition. Technology was key to the success of the large truckload firms that came to dominate (Baker and Hubbard 2000; Hubbard 2000). Truckload firms often send trucks from one point to another and then find the closest available load with little regard for the destination and then repeat the process. This leads drivers—paid by miles driven—to work over large geographic areas for weeks at a time. It also yields hours of unpaid waiting, more time away from home, and, ultimately, increased driver turnover (Viscelli 2016). In response to a lack of experienced drivers willing to do the job, large carriers adopted satellite-linked computers and other technologies to de-skill the job. These technologies include automated mapping, automatic transmissions, forward collision avoidance, and management systems reliant on on-board computers. The latter systems allow firms to monitor and manage workers directly from afar (Levy 2015, 2016).

Previous adoption of technology in trucking lays bare the importance of public policy and worker power. Where truckers remain unionized or experienced, as in LTL, parcel, and private trucking, some technologies, such as tracking and communication systems, have been widely adopted; yet, jobs are well compensated and of high quality. In long-haul truckload and port hauling, where workers are institutionally weak and many labor and safety rules remain unenforced, technology has been used to de-skill trucking work, speed it up, and keep wages low (Viscelli 2016).

The Development of Self-Driving Trucks

As recently as 2004, self-driving vehicles were considered technologically infeasible and therefore unlikely to be deployed widely (Levy and Murnane 2004). Yet in 2010, Google revealed a small fleet of self-driving cars. What happened in the intervening six years was a "mini-moon shot" carried out by the Defense Advanced Research Projects Agency (DARPA), a research and development agency for the US Department of Defense. The 2001 National Defense Authorization Act (S.2549, Sec. 217) had set a goal that the armed forces have one-third of ground combat vehicles unmanned by 2015. DARPA issued a challenge to industry, academia, and "tinkerers" in its 2004 Grand Challenge, which offered a $1 million prize to the team that could build an unmanned vehicle that could complete a 300-mile desert course between Nevada and Los Angeles in the shortest time.

The Grand Challenge attracted a wide range of participants and sponsors, but the stars of the challenge were academic teams from the nation's leading computer science and engineering departments. No team made it more than a few miles on the 142-mile course from Barstow, California, to Primm, Nevada, in 2004. And, while the event was panned by the press as a "debacle in the desert," DARPA's leadership was thrilled. Several more challenges followed over the next three years and focused the work of thousands of roboticists and computer scientists on self-driving technology. Dozens of key participants in this project went on to work on self-driving technology at major auto manufacturers, Google, Tesla, Apple, Uber, and Lyft, in addition to dozens of start-ups. In interviews, every founder or leader of self-driving programs and companies cited DARPA's efforts as the reason self-driving technology is a possibility today.

Currently, all of the US and European major car manufacturers and many suppliers are working on or planning for self-driving technology. Teams of hundreds of scientists and engineers and billions of dollars are targeted at self-driving trucks as one of the first commercially and technologically viable products to arise from self-driving technology.

Most developers approach the challenge of self-driving trucks similarly. While a few observers have suggested a broader control infrastructure could be used to coordinate the movement of vehicles on public roads (similar to air traffic control systems), most developers envision sophisticated robotic vehicles capable of independent, self-directed operation. Such robots perform three basic sets of tasks. First, they must figure out where they are and what is around them. Self-driving trucks do that using highly detailed "base" maps and a wide array of sensors. Second, the trucks use programming and machine learning to predict what the actors and elements around them are going to do and what they should do in response. And, finally, computer systems processing all that data and making decisions must control the various components of the vehicles to drive them.

Possible Policy Pathways for Self-Driving Technology in Trucking

At present, self-driving trucks cannot handle the complexity of non-highway environments with pedestrians, parked cars, intersections, and so on. While a few developers have suggested that self-driving trucks could be piloted through local environments remotely by human operators from a control center, most developers have rejected this solution as technologically unrealistic and unachievable in the near and medium term.

As a result, developers envision self-driving trucks driving mostly on highways. Still, self-driving trucks would have transformative impacts on freight movement. They will be cheaper to operate, causing shippers to substitute transportation for other logistics costs. Cheaper trucking will also mean a modal shift from rail to truck. Since rail is three to four times more fuel efficient than trucking and does not directly cause roadway congestion and wear-and-tear, this shift will have significant impacts on the environment and the public.

Self-driving trucks will also operate more hours per day than the typical truck today. Once trucks operate for 18 or 20 hours a day, the distances traveled in a day could be doubled or trebled. Supply chains would then require fewer facilities to supply stores and service customers, remaking the geography of our logistics infrastructure and work.

Beyond these general capabilities and effects, however, the exact uses and impacts on the industry's workforce are less clear. A closer look at two possible use scenarios highlights the potential influence of policy.

Self-driving trucks operating on highways will affect for-hire truckload and terminal-to-terminal trips in LTL operations most extensively, because those are the segments that entail the most uninterrupted highway driving. The question is whether a human remains in the truck while the trucks drive themselves. In other words, will these self-driving trucks also be *driverless* trucks?

On the one hand, if a human remains, the process is much simpler: A human drives the truck out to the relatively navigable interstate highway, where the technology assumes the driving. When the truck exits the highway for local surface roads, the human again assumes the wheel.

If the human is removed, on the other hand, the process would require three separate vehicles and two human drivers. One driver would bring the trailer out to a transfer lot and uncouple the trailer. The trailer would then be coupled to a self-driving tractor and hauled over the long-distance portion of its trip. At the other end of the trip, the trailer would be uncoupled from the self-driving tractor and coupled again with a human-driven tractor for final delivery. Note though that if the self-driving truck should encounter difficulty while on the highway, no human would be there to attend to it.

Both scenarios present important policy questions. Leaving the driver in the truck could further degrade the working conditions of drivers by breaking their workday into smaller amounts of local driving and non-driving work. It would further de-skill the work as the machine would do the dangerous, high-speed driving. This could reinforce the industry's practice of recruiting and using public subsidies to train workers completely unfamiliar with the industry rather than raising wages to attract and retain skilled labor.

So, how much would it cost to leave drivers in place? The answer depends on whether the time the truck is driving itself counts as work time for the human, and the extent to which this work time is compensable, if at all. Hours of service (HOS) rules govern the work of truckers. The Federal Motor Carrier Safety Administration, part of the US Department of Transportation (USDOT) sets HOS rules, which are intended to prevent crashes by limiting fatigue. Drivers' working and non-working time must be recorded as one of four statuses—off duty; in sleeper berth; on duty, driving; or on duty, not driving. If HOS rules state that human drivers are on duty even when the computer is driving—perhaps because the driver retains some role in monitoring the system—the self-driving scenario with a driver still in the truck could be prohibitively expensive.

Even if the time a truck is driving itself is considered off duty under USDOT rules, that time might still need to be compensated. Under current US Department of Labor guidance, truckers who are away from home for more than 24 hours are entitled to at least minimum wages for all that time, though eight hours of sleep can potentially be excluded. For decades, large truckload carriers have routinely violated minimum wage laws by using USDOT on-duty hours as the basis for compensability. Several class action lawsuits are now challenging this practice. If drivers are entitled to minimum wage the entire time the truck is driving itself or 24 hours a day, it would strengthen the case for removing drivers entirely.

Finally, many firms currently use independent contractors, who are much cheaper than employees because drivers themselves pay all the costs associated with the truck they drive. The practice also relieves firms of their obligation to make contributions toward Social Security and Medicare. While the trucking industry continues to claim independent contractors are part of a long-standing tradition of owner-operators, the relationship has been transformed by technology and the associated management systems that allow carriers to monitor and manage truckers while they work (Viscelli 2016). If self-driving trucks cannot be used with workers classified as independent contractors, the technology will strongly favor scenarios in which drivers are removed from trucks entirely.

Conclusion

Self-driving trucks will result in more goods movement by truck. That development will contribute to the broader transformation of goods movement already underway because of e-commerce and rapidly growing demand for last-mile delivery to customer residences. Strategic government investment created that technology, but the impacts will be shaped by long-standing labor issues in the industry, the immediate supply chain crisis created by COVID, and public policy.

Without a robust and comprehensive policy response to self-driving technology, we can expect that the trucking industry's historical practice of using technology to de-skill drivers, and its lack of compliance with basic worker and safety protections, will continue. For many workers this will mean bad jobs and low wages. We could avoid those outcomes by enforcing existing policies, such as minimum wages, and by altering others: consider, for example, ensuring that public monies support training programs that provide successful career paths rather than high-turnover jobs of low quality. We could also extend the overtime protections of the Fair Labor Standards Act to interstate truckers, who are not currently entitled to overtime. More broadly, policymakers could work to ensure that those jobs most affected by self-driving technology are "good" jobs in which workers are compensated for all of the time the work requires.

TECHNOLOGY ADOPTION AND THE FUTURE OF WAREHOUSE WORK

BETH GUTELIUS AND NIK THEODORE*

Technology has transformed the way people shop, fueling the meteoric growth of e-commerce. With a click, customers now expect merchandise to arrive at their door—sometimes the very same day, which is a sea change from even a few years ago. Although some of the ripple effects of e-commerce on goods distribution are conspicuous—such as the legions of last-mile delivery drivers on city streets—others are largely hidden from view, tucked away in cavernous buildings in industrial parks where warehouse workers hustle to assemble orders. While competitive pressures are especially intense in the e-commerce sector, warehouse operators in all markets face challenges with efficient goods distribution. Competition is increasingly centered on low-cost, high-speed order fulfillment, triggered by Amazon's standard-setting delivery promises, and warehouse operators are now exploring new technologies in an effort to keep pace with soaring consumer demand.

In this essay, we identify factors that are motivating warehouse operators to implement new technologies as well as those constraining adoption, and we analyze the potential impacts of technological advances on work and workers. Warehouse operators have many reasons for wanting to make technological investments, particularly in times of tight labor markets. However, despite reports that new technologies are rapidly gaining ground, constraints endemic to the warehousing industry—namely product variability,

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outsourcing arrangements, and organizational inertia—create headwinds that have slowed the pace of change.

We draw on interviews conducted between 2013 and 2021 with 81 industry leaders and analysts, including warehouse operators, retailers, brands, management consultants, and technology providers. Interviews were conducted in person and via telephone and ranged from 60 to 90 minutes. We also draw on proceedings from three supply-chain management conferences in 2020 and 2021, comprising 68 individuals across 30 sessions, as well as supplementary analysis from government sources and industry trade publications.

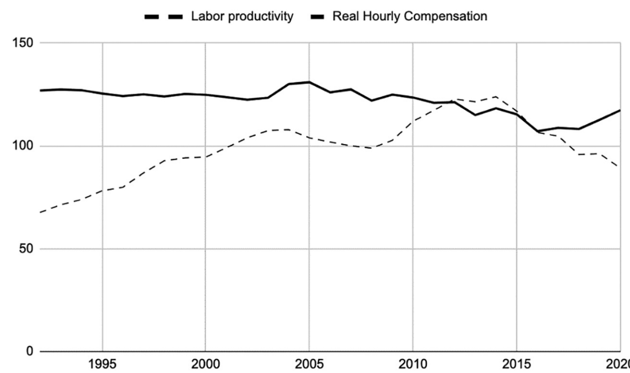
We characterize the warehousing industry as being at an early stage of technology adoption; the main drivers are to reduce labor costs and improve productivity, with reductions in real estate costs and throughput time as additional factors. Our field research identifies two overarching effects on labor. On one hand, technological advances are reducing the quality of many jobs through de-skilling and intensifying both the pace of work and the monitoring of worker productivity. On the other hand, new technologies will reduce the labor content of work processes, slowing employment growth even as demand rises. Finally, these changes especially affect Black and Hispanic workers, who constitute 61% of the frontline workforce, as well as men, who make up 72% of the workforce (American Community Survey 2013–2017).

Warehouse Industry Context

E-commerce is increasing pressure on warehouse operators to move more goods with greater speed—all while holding down costs. Consumer and retailer expectations for on-time delivery and accurate order fulfillment are high, and in most distribution facilities volumes have risen sharply. Even warehouses that do not fulfill online orders report heightened pressures to improve efficiencies and reduce costs.

Traditionally, warehouse operators have responded to demand increases by accelerating hiring, often of temporary workers, who make up approximately one-quarter of the workforce (Armstrong & Associates 2021). In the wake of the COVID-19 pandemic, however, a common refrain among managers is that the industry is facing acute labor shortages (Korn Ferry 2021). Warehouse employment has increased steadily since the mid-2010s, mirroring the ascendance of e-commerce as a key facet of modern retail. Warehousing now employs nearly 1.5 million US workers (US Bureau of Labor Statistics 2021c), the vast majority of whom perform manual activities. Compensation levels, however, have not seen comparable gains; to the contrary, even though it rose during the pandemic, real hourly compensation of warehouse workers was lower in 2020 ($18.58) than in 1992 ($20.73) (see Figure 4). Furthermore, over the past three decades, warehouse workers' earnings have become decoupled from changes in productivity. Between 1990 and the mid-2010s, rising productivity was not met by increasing worker compensation, whereas in the period 2016 to 2020 compensation

Figure 4. Labor Productivity and Real Hourly Compensation for Warehouse Employees, 1992–2020



Source: US Bureau of Labor Statistics (2021a).

Notes: Both measures indexed (2007=100). Wages in 2020 dollars using the BLS Consumer Price Index.

rose even as productivity fell, a divergent pattern that likely is the result of growth in labor-intensive e-commerce operations. Historically stagnant wages, combined with physically demanding work and stunted career paths, have seen job seekers slow to fill vacancies. Nevertheless, in this notoriously low-margin industry, managers have been loath to raise wages. As a result, there is growing concern among warehouse operators that their primary means of coping with rising demand—employing contingent workers—will soon be rendered impractical.

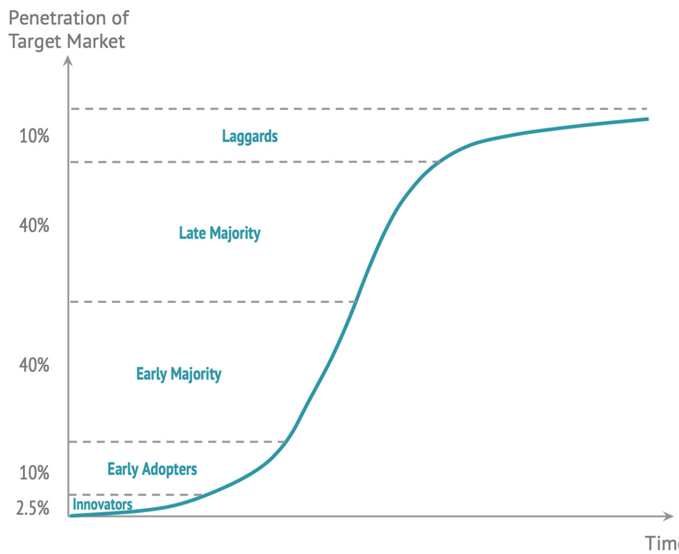
Technological advances potentially offer an alternative to increasing headcount as a way to keep pace with rising demand. Despite warehousing historically being a laggard industry in terms of technology adoption, warehouse operators stand to gain substantial efficiencies through such investments. That said, most operators face significant impediments.

Factors Driving and Constraining Technology Adoption

In his landmark study of the diffusion of innovations, Rogers (1962) highlighted the role that social structures play in shaping the pathways of technology adoption. The extent and rate of adoption in an industry is related to multiple factors; chief among them are the relative advantages conferred by new technologies, the complexity of implementation, and the compatibility of a given technology with users' workplace norms and systems. These factors help account for the marked unevenness of technology adoption across a sector, as well as the variable pace of change. The path of adoption of a given innovation typically resembles an S-curve, progressing from innovators to early adopters to late adopters (see Figure 5). The warehousing industry remains in the lower left of the model, that is, an industry just beginning the process of new technology diffusion.

The notable exception to the overall sluggish pace of technology adoption is warehouse management systems (WMSs), which are used in roughly two-thirds of facilities (Tillman, Manrodt, and Williams 2018).

Figure 5. Diffusion of Innovation



Source: Based on Rogers (1962).

These systems control day-to-day operations, including receiving and order staging. During the 1980s and 1990s, many warehouse operators developed proprietary WMSs, and the unique attributes of their software solutions helped solidify their market position (Feffer 2017). Today, warehouse operators are replacing these legacy systems with sophisticated off-the-shelf software packages, which represent an initial step toward modernizing warehouse operations since they are a prerequisite for the implementation of other technologies. These technologies include autonomous mobile robots, voice-directed picking systems, and robotic arms, which we discuss below. Estimates of efficiency gains from new technologies vary widely by type of facility and technology. For example, 6 River Systems makes an autonomous mobile robot that promises to help customers increase productivity by 10% or more (Koppelman 2020); GXO claims to have realized a 43% gain in efficiency at one site during a pilot trial of the same product (Demaitre 2021).

Notwithstanding the extent of WMSs across warehouse facilities, the uptake of other technologies remains uneven. We find that pathways for adoption are influenced by a multifaceted set of factors shaping warehouse operators' decisions regarding how and when to apply new technologies. The key objective of most technology investment in warehousing is reducing labor requirements. Warehouse operators commonly cite difficulties securing an adequate workforce: In a 2021 survey, for example, 97% of warehouse operators reported difficulties hiring frontline workers (Korn Ferry 2021). Facing exceedingly narrow margins, in the range of 4 to 5% for outsourced warehousing (Coe 2021), some managers have responded to the resultant constraints placed on wage increases by experimenting with an array of labor strategies. These include offering bonuses, improving benefits packages, and deepening reliance on temporary staffing agencies (Gutelius 2015; De Lara 2018), while other managers have sought out previously overlooked labor forces, such as persons with disabilities (ProLogistix 2015) and older workers (Bruder 2017).

Crucially for the longer-term restructuring of industry labor markets, many warehouse operators also report that rising recruitment costs are prompting their exploration of how new technologies might reduce the number of workers required. Several technologies promise to reduce labor costs, either by replacing workers or by speeding them up. For example, to reduce workers' time spent walking and sorting, the first wave of warehouse mechanization in the 1980s focused on conveyors and sortation systems to transport boxes across large expanses and direct goods to the proper shipping location. Autonomous mobile robots (AMRs), a more recent innovation that is seeing increased use, serve a similar function, ferrying goods between order selection and shipping stations without human intervention. And autonomous guided vehicles (AGVs), another newer technology, are either fully or partially automated forklifts that can reduce reliance on forklift operators, the highest-paid frontline warehouse occupation.

Other technologies allow for close monitoring of worker productivity. Radio frequency (RF) scanners, which are devices used to read product barcodes, operate in conjunction with WMSs to manage inventory and order-picking processes. RF scanners, which have been available since the 1990s, also allow managers to monitor productivity by tracking the time it takes a worker to select and scan each item and then comparing the time between scans to occupational benchmarks or to the pace of co-workers. Sensors placed on workers' bodies offer similar monitoring of their movements, though at an even finer scale, and are just beginning to see wider application in warehouses. Scanners and sensors are overseen by managers or by algorithms that instantaneously analyze data about workers' performance and provide feedback to managers and frontline workers.

Given the cost sensitivity of warehousing, rising real-estate expenditures represent an additional strain on the bottom lines of warehouse operators. Average rents for warehouse space have risen every quarter since 2014 (Morley 2019), and as e-commerce expands, demand for space will grow (Trebilcock 2018). Together, these factors increase the attractiveness of technologies that reduce both labor needs and floor space requirements. One such technology, automated storage and retrieval systems (ASRSs), combines efficient storage options with automated shuttles that deliver goods to workers at picking and packing stations. In ASRSs, goods are stored on racks that eliminate the need for aisles, thereby increasing storage space and reducing workers' time spent locating items.

Another factor driving technology adoption is the heightened demand for rapid order fulfillment. Rising consumer expectations coupled with falling revenues from shipping have forced many retailers to rethink their distribution strategies, including how technology could increase the speed of order fulfillment. The time frame in which customers expect to receive their orders, which is being set by Amazon's sophisticated logistics network, requires many orders be filled within hours of receipt. At the same time, customers now expect shipping and returns to be free of charge. All of this translates into the need for greater throughput. Voice-directed picking systems include headsets worn by workers that provide instructions about which items to pick and where they are located, which can increase the pace and accuracy of order picking. As mentioned above, ASRSs and AMRs can also speed operations by minimizing workers' non-productive time. Finally, robotic order picking, in which a robotic arm equipped with hand-like or suction-cup grippers reaches into a pick location, grasps an item, and places it into a tote, is an emerging labor-saving technology that can also increase throughput.

Despite the potential benefits of technology adoption for warehouse operators, however, they face various constraints that have slowed the pace of implementation, though some of these are easing. Variability, including in product size and order volume, is common in distribution centers. Little standardization exists across goods, particularly in terms of product dimensions and weight, so warehouse operators continue to depend on human labor to cope with product variation. Exceptions include facilities in which goods are relatively uniform, such as apparel, where standardization renders robotic picking feasible. As this technology becomes more sophisticated, its use will expand beyond such narrow applications.

Demand variability creates additional challenges. Warehouse operators have been hampered in their responses to order-volume volatility because the forms of automation available have been costly, inflexible, and difficult to scale. A conveyor system, for example, cannot hold more goods or run faster. Managers instead have traditionally responded by adding shifts and hiring larger numbers of contingent workers. Today, however, newer forms of automation, such as AMRs and voice-directed systems, are more modular, flexible, and scalable. Because the industry is in a liminal state of technology adoption, the implementation of new technologies is now occurring alongside the swelling ranks of temporary workers, whose dexterity is still required and whose contingency allows managers to closely calibrate staffing levels to fluctuating order volumes.

Another constraint to technology adoption is the widespread use of outsourcing by lead firms. Warehouse outsourcing is pervasive and growing (in a recent survey, 58% of companies reported they were planning to increase outsourcing of logistics operations [Langley and Capgemini 2017]), yet subcontracting itself can pose impediments to technological investment. First, technologies purchased for one client are not guaranteed to be transferable to others. Second, the most advanced technologies are too expensive for most warehouse subcontractors. Third, because the industry relies on contracts that span three or fewer years (Gutelius and Theodore 2019; Armstrong & Associates 2021), it might be impossible for a warehouse to achieve an adequate return on costly technology investments. Some outsourced warehouses are responding to this latter constraint by positioning themselves as technical assistance providers that offer a range of workable technologies for clients, thus modifying their value proposition. With the possible exception of leading online retailers, however, clients continue to regard warehousing mainly as a cost to be minimized, not a value-adding activity (Coe 2021).

Finally, organizational inertia arises from the ways in which warehouse facilities have been designed and operated, which narrows the scope for technological change. First, existing systems of mechanization, such as industrial conveyors, required major capital investments, and companies have been understandably slow to abandon these systems. Second, fear of change can deter warehouse operators from undertaking the actions needed to incorporate new technologies into their facilities (Proctor and Fowler 2019). Third, the sheer cost of technological upgrades and, for some smaller warehouse operators, difficulties in achieving economies of scale, can hinder investment. Together these factors remain powerful constraints on technology adoption.

Technology's Impact on Warehouse Workers

Despite the fact that the adoption of new warehousing technologies is at an early stage and proceeding unevenly, two overarching effects on labor emerge from our research. On the one hand, technology adoption is reducing the quality of existing jobs—by de-skilling them and by intensifying the pace of work through new means of monitoring worker productivity. On the other hand, over the long term, new technologies will reduce the labor content of warehouse functions, hence slowing employment growth even as demand rises.

In facilities that have limited ability to adopt labor-saving technologies because of the constraints we identify above, warehouse operators manage product and demand variability primarily through workforce strategies (e.g., increasing overtime or deepening reliance on temporary workers) rather than through automation. As long as workers' wages remain relatively low, many warehouse operators will continue to delay investments in new systems, especially given that automation introduces new complexities into established operations.

In warehouses with fewer constraints on technology adoption, managers are transforming distribution functions as well as workers' experiences on the job. First, some technologies decrease the skill requirements of occupations, which can reduce training times and therefore turnover costs. An interviewee, the distribution center manager for a large department store chain, recounted the following from a sales conversation with a representative of a leading warehouse robotics company, who explained, "[order picking with our robot] is something that obviously your core staff can do, but you can bring a temp in off the street, and they can be fully functional in a very short period of time." In some cases, de-skilling through technology upgrading appears to be motivated by a desire to shift labor strategy by expanding the labor market, increasing the use of temporary workers, or reducing the workforce in certain occupations.

Second, although advanced technologies could alleviate the need for workers to undertake arduous tasks (such as heavy lifting), our research shows that adoption of these technologies is often coupled with increases in workloads and the pace of work. For example, we found that voice-directed picking and ASRSs have increased productivity by limiting employees' ability to interact with each other, which could slow the pace of work, and by pushing them to perform at faster speeds. Work intensification, in turn, introduces new health and safety risks, and increases employee turnover due to overwork and workplace injuries. Amazon provides an example of these hazards. The Washington State Department of Labor and Industries (2021) recently cited health and safety violations at an Amazon warehouse, with its investigation finding that "employees are expected to maintain a very high pace of work; . . . pressure is put on workers to maintain that pace without adequate recovery time to reduce the risk of MSDs [musculoskeletal disorders]. There is a direct connection between Amazon's employee monitoring and discipline systems and workplace MSDs."

Third, the adoption of advanced technologies has been accompanied by electronically mediated forms of monitoring and micro-management that undermine workers' autonomy. Increasingly sophisticated software allows for "digital Taylorism," whereby engineered labor standards are augmented by machine learning and the automated monitoring of workers. Algorithmic management introduces new forms of workplace control, in which the technological regulation of workers' performance is granular, scalable, and relentless.

Conclusion

Our research shows that the warehousing industry has been marked by slow and uneven adoption of new technologies. For warehouse operators, technological advances are attracting increasing interest, largely because they offer opportunities to reduce labor costs and improve productivity, with reductions in real estate costs and throughput time as additional benefits. Despite these advantages, however, warehouse operators are constrained by product and consumer demand variability, outsourcing dynamics, and organizational inertia, which have combined to slow the overall pace of change.

The warehousing industry could realize significant operational improvements through technological advances—and it is imperative that productivity gains are shared, that workers are involved in identifying which efficiencies should be pursued and what hazards are being introduced, and that experimentation unfolds with regard for workers' well-being and not simply productivity increases and cost reductions. Absent such shifts in managerial priorities, technological change will result in a win–lose proposition, in which short-term benefits are captured by the warehousing industry while the long-run costs are borne by its workers.

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