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COVID-19's Impact Upon Labor and Value Chains in the Agrifood System

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ABSTRACT
We explore the impact of automation and digitalization on labor in the US agrifood system during the COVID-19 pandemic. This study considers each of the primary nodes in the system stretching from consumer through grocery stores and restaurants to last-mile delivery, distribution, food processing, farming, and agri-inputs. Not only automation and digitalization, but also the role of platforms such as Amazon, and food delivery firms such as GrubHub, Instacart, and Uber Eats are discussed. For restaurants, we consider not only dine-in restaurants, but also "ghost kitchens". Furthermore, the possibility that farmers or distributors could disintermediate other nodes and deal directly with consumers is discussed. We conclude that, as a generalization, the further upstream one goes from the consumer, the less immediate and disruptive automation is likely to be for labor. However, our overall conclusion is that, given the current trajectories, labor is becoming increasingly precarious. If the current labor shortages continue, then automation is likely to accelerate. Platformization, while rampant in the relationships with final consumers, is likely to be less rapidly adopted further upstream where relationships are B-to-B and thus composed of actors that are wary of sharing data.

Keywords: Digitization, Platform Economy, Agrifood Systems, Labor, Covid, Automation

1. Introduction

The COVID-19 pandemic (hereafter COVID), which began in early 2020 and rapidly spread around the world, was facilitated by the easy and cost-effective global nature of travel and human movement. The highly infectious nature and high mortality rate of the virus resulted in many countries and individuals curtailing travel and in-person events, instituting quarantines and lockdowns, closing restaurants, and limiting capacity at retail establishments in order to stop the spread of the virus. The impacts of such responses were felt throughout the US agrifood system as severe COVID outbreaks occurred in food processing facilities, slaughterhouses, fruit and vegetable packing facilities, warehouses, and many other parts of the system that were deemed essential and continued to operate throughout the pandemic.

On March 19, 2020, still quite early in the pandemic, the federal government designated food and agricultural sector workers as essential workers (Department of Homeland Security, 2020). This raised questions about workplace and occupational safety for workers in the system, as well as the need to ensure a stable and reliable food system and network to continue to reach consumers as global food value chains were disrupted by port closures, shipping and port handling delays, and labor shortages. Responses to these developments included the rapid change in consumer usage of internet-enabled platforms and food delivery systems, and the accelerated introduction of automation throughout the many sections of the agrifood system; all of which are having and will continue to have an impact on labor, labor processes, and inter-firm competition.

The discussion that follows focuses on the impact of COVID on agriculture and the agrifood system in the US. As such, our analysis is unique given the particularities of the US context including a large power imbalance between labor and capital, weak unions, as well as weak regulatory structures across all areas including the environment, securities, and labor, in addition to a deeply financialized political economy. In technological terms, it is important to

note that in the advanced digital technologies—with the possible exception of China—the US and US firms continue to be the global leaders. The US also has the most developed entrepreneurial ecosystem fed by enormous amounts of venture capital and other intermediaries. Finally, it has a huge and unified internal market for all manner of products and is the world's largest producer and exporter of agricultural products. As such, it is likely that the US context may have facilitated a faster uptake in digitalization and automation. While these characteristics make the US case unique, there are many lessons that can be generalizable to other contexts and settings and general trends are likely to remain the same across the global economy.

This paper examines the impact of increasing use of both automation in, and the increased digitalization of, the US agrifood system. Increasing digitalization of the agrifood system includes what is often colloquially referred to as "AgTech" throughout the industry. AgTech encompasses technology focused businesses and improvements within agribusiness as well. Such businesses may produce agricultural commodities, purchase agricultural produce, or supply goods and services to farms. Many scholars use the term AgTech to describe digitalization of processes that lead up to, but exclude, the point of retail sale. We go beyond this definition by focusing on digitalization broadly throughout the entire agrifood system, including the important and vastly digitalizing retailer to consumer segment of the system.

The paper proceeds as follows. In the following section, we begin by discussing the contours of the debate and questions surrounding the impact of automation and digitalization in US agriculture on work in the agrifood system. We limit our analysis to the question of how COVID and the shocks the pandemic presented to the US agrifood system likely impacted existing trends in automation and digitalization and the implications this presents for actors and workers engaged in the agrifood system. We then turn to providing an overview of

the agrifood system in the US, outlining its vast contours and identifying four nodes of activity. Next, we discuss the impact of COVID on these four nodes in turn, and assess to what extent such impacts are likely temporary, permanent, or inconsequential in influencing automation and digitalization in the industry and their direct and tangential impact on workers. We argue that, while all segments of the US agrifood system experienced increasing digitalization and automation under the rapid and constantly changing conditions of the pandemic, the impact of COVID was most significant for industry, actors, and labor in relation to the farm to consumer segment of the system—that is the warehouse to distributor and retail to consumer segments. Furthermore, we argue that these impacts have both the potential to significantly reshape these segments of the agrifood system as well as working conditions in these segments over the long term—particularly in light of labor shortages which currently plague these sectors of the agrifood system. We close our discussion by examining the implications such impacts present for the US agrifood system and implications for government, industry, and labor.

2. COVID-19, Automation, and Digitalization in the US agrifood System

The debate about the future of work under technological advancements and the rise of AI precedes the COVID pandemic, so much so that Frey and Osborne (2017) predicted a tidal wave of substitution of capital (automation) for labor long before industry practices and public health policies may have necessitated their fast adoption.[1] However, many economists were more measured in their assessment of the impact of these technologies, but also expected significant automation-derived unemployment (Autor and Salomons 2018; Acemoglu and Restrepo, 2018). Some were more sanguine, expecting that automation would create more jobs than were displaced (Bessen, 2019). There is also a large body of research in

[1] This paper cannot address the ongoing debate about whether the job loss and wage stagnation over the last 25 years was caused by job-offshoring, the demise of unions, or labor-saving capital investments.

the social sciences that has examined the relative tendency of labor markets in advanced economies—projected to be highly impacted by digitization—to trend toward polarization and discussions on whether or not jobs in the middle of the wage and skill distributions have experienced relative decline in light of such technologies (Wright & Dwyer, 2003). This body of work has sought to interrogate theories of skill biased technology change and suggests that advances in ICT and digitalization have generated a shift in employment to favor higher skilled workers (Ciarli, 2021). It has also been suggested that minimum wage laws and declining union density influence polarization, but evidence of the impact of these factors remains inconclusive and outside the scope of this paper (Autor, 2010).

During the pandemic, factories and, in fact, any work undertaken inside of closed buildings, were significant loci for the spread of COVID and quickly experienced shutdowns beginning in March 2020 (Cleeland 2020). Factory work was among one of the prime candidates for further automation and research suggests that the work identified by Frey and Osborne (2017) as automatable did in fact experience significant employment declines in 2020 (Ding & Molina, 2020). Yet, the jobs and industries most impacted by the COVID pandemic were leisure, hospitality, and other service industries where lockdowns and the demise of tourism and leisure activities (i.e. dining) were devastating (Lee et al., 2021). In the first phase of the COVID pandemic, the dominant theme continued to be digitalization and platformization, which was advancing under the new normal of separation and distance fueled by, and in turn fueled, the changing character of the activities and various work processes. Such changes were so vast that Knight (2021) argued that increasing pandemic-driven

automation would replace workers[2] and result in a possibly permanent unemployment problem (Smith, 2021).[3]

In late 2021, labor shortages occurred across industries, brought on by lockdowns, increasing demands of working families, and perhaps a reluctance of labor—particularly in the service and retail sectors of the US economy. As a result, wages began to increase (simultaneously, so did inflation). Such dynamics have particular implications for the agrifood system as it has a long history of low pay and significant turnover. This has led to increasing digitalization in segments of the agrifood industry that had once relied on human labor, including the use of QR codes to both order and pay through smartphones at dining establishments, the use of on-demand food and grocery delivery services, and the rise of self-checkouts at retail establishments. Thus the general trend of developing automation and increasing digitalization throughout the first phase of the COVID pandemic has been characterized by two stages. An early stage aimed at responding to the need to decrease close human interaction (and particularly face-to-face interaction), and a later stage that is continuing to emerge as a potential response to labor shortages.

Together, these dynamics suggest that digitalization and automation, while already underway throughout the US economy, were impacted by the shocks to the economic processes and value chains that COVID presented. The adaptation of technologies used to reduce close human interaction, to ensure efficient production in the face of the need to reduce occupancy in poorly ventilated areas, as well as an increasing adoption of technology to aid in response to a growing labor shortage is likely to have three possible impacts on trends already existing in various sectors of the US economy. The agrifood system is one such

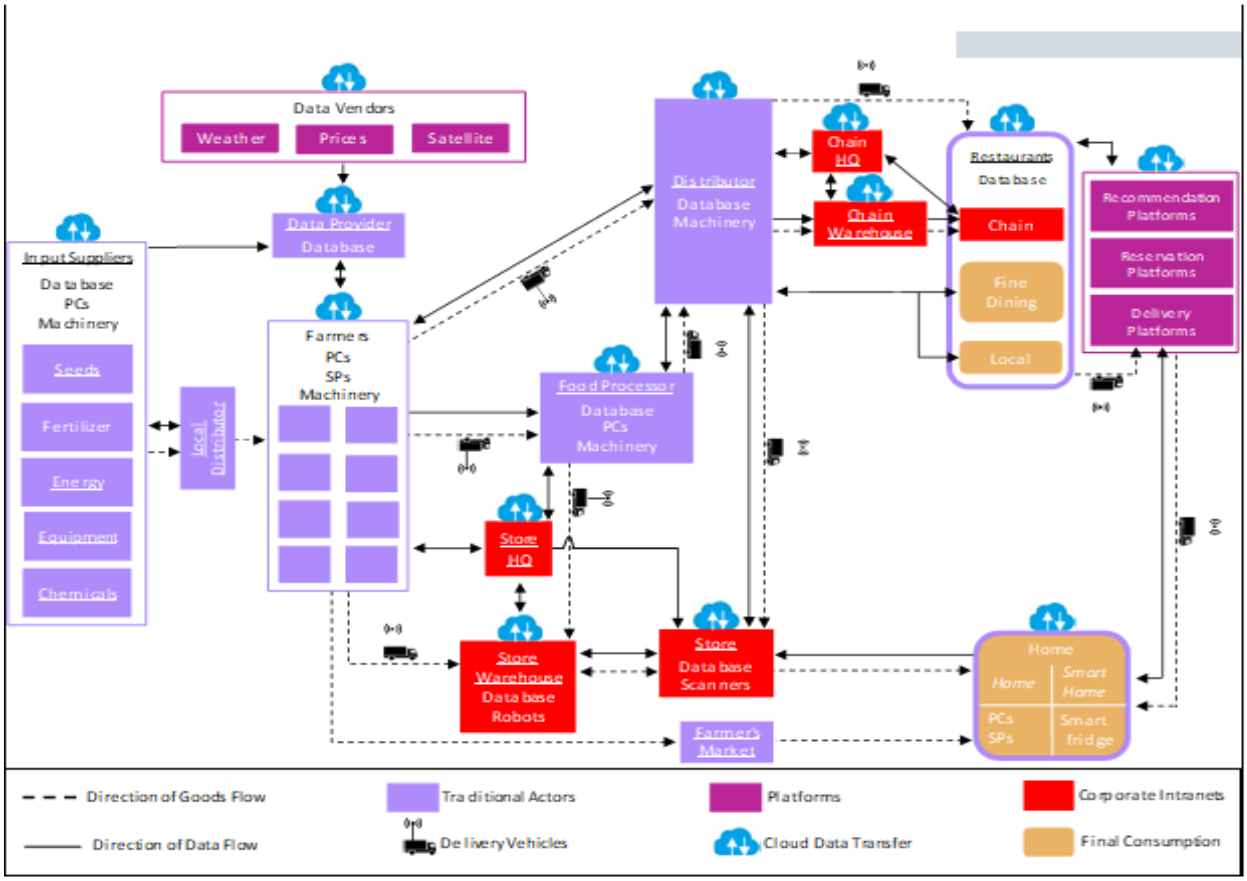
[2] Knight, W. (2021, June 7). COVID Brings Automation to the Workplace, Killing Some Jobs. *Wired.* https://www.wired.com/story/COVID-brings-automation-workplace-killing-some-jobs/
[3] Smith, J. (2021, May 24). Warehouses look to robots to fill labor gaps, speed deliveries. *The Wall Street Journal*. https://www.wsj.com/articles/warehouses-look-to-robots-to-fill-labor-gaps-speed-deliveries-11621878163

sector where the adoption and rise of automation and digital technologies was fueled by the factors identified above and the adoption of such technologies is likely to have either have deaccelerated, accelerated, or have an inconsequential impact on the trend that already existed in this sector of the US economy. In the next section, we provide an overview of the US agrifood system and delineate the four primary nodes to describe previously existing trends in automation and digitalization that existed prior to the COVID pandemic.

3. The US agrifood System

The agrifood system is a value chain from the agro-inputs industry that includes many actors, processes, and equipment types—from farm and food processing equipment through farmers and food processors to the final consumer. The agrifood value chain is simple and yet quite complex, with different market conditions defining each node in the chain and each system consisting of a great variety of products, each with its own value chain. Each node might have multiple software systems that do not intercommunicate, despite the development of international interface standards for interconnecting agricultural implements (e.g., ISO 11783). **Figure 1** is a simplified visual representation of the system.

Figure 1: Agrifood System Value Chain Depiction



While the system is complex, for analytical purposes we divide the system into relationships between and within four nodes. Nearly every node in this chain is already digitized and will likely adopt more digital technologies in the future. Ultimately, this provides the opportunity to link all of these together. However, at this time, it is still possible to consider each segment separately to understand the impacts of COVID on work and labor operations in each of the nodes. Below we describe each of these nodes briefly.

3.1. Retail and Restaurants to Final Consumer

This node can be divided into four activities: final consumer, delivery, food retailing, restaurants; each of which we examine in turn below. Traditionally, this segment of the agrifood system has entailed the process of consumers going to a store or restaurant to select and buy their food to be consumed there or taken home by the consumer. However, over the

last few years, operations in this segment have been experiencing significant changes due to the broad-based advances in computation and software.

3.1.1. Consumers

Over the last two decades, consumers have become connected to the Internet first through personal computers, but, more recently, increasing amounts of commerce have gone through smartphones and apps that seek to connect the consumer directly to distributors themselves. In China, for example, smartphones have become the medium of payment for nearly all daily commerce including food. Such mediums are becoming increasingly popular in the US through apps like PayPal, Apple Pay, and Venmo. In restaurants, menus are equipped with QR codes, easing order-taking and also automating the payment process. Restaurants not only accelerated the automation of the payment process in response to COVID19, but also had to further develop new digital methods to connect with consumers -- a trend that is expected to continue in the future. The need to social distance and the closure of the majority of indoor dining forced many restaurants to discover new ways to advertise and market to consumers.

Social media platforms such as Instagram, TikTok, and Facebook have been employed to advertise menus, products, and delivery services. Restaurants and consumers alike have also become reliant on content platforms, such as The Infatuation and Eater, websites that have in the past served as sources of information for consumers, but in the pandemic took on a more central role as an intermediary forf information regarding current services, safety measures, and business hours (Ajao, 2020). While not nearly as advanced as China, in the US, the ubiquity of internet connectivity and smart phones and the availability of people with cars willing to work on a gig basis, had already given rise to home food delivery prior to the pandemic, particularly from restaurants through platforms such as Instacart, DoorDash, PostMates (now Uber Eats), and others.

While there has been discussion of smart appliances such as smart refrigerators that would automatically reorder out-of-stock products, there has been limited uptake on this functionality. At this point, automatic reordering has not been adopted by US consumers outside of app-based purchases, such as automatic reordering through subscriptions with Amazon or Walmart, which set up automatic reorders but are still dependent on the consumer to make the determination rather than a smart appliance. In the next section, we discuss platform-mediated delivery and consider the work process and its implications.

3.1.2. Delivery: The Emergence of a New Intermediary

Prior to the pandemic, digitalization was redefining the value chain and labor processes across the agrifood system were being organized. Prior to the COVID pandemic, consumers were already adopting smartphone-enabled delivery, but the pandemic dramatically accelerated the adoption and usage of app-based home delivery for food (among many other products), from both retailers and restaurants. While it is uncertain to what extent consumers will continue to use home delivery, it is certain that it will not decline to the status quo ante.

Home delivery, of course, has a long history, including the willingness of restaurants to deliver food—work that was often undertaken by either employees or someone affiliated with the restaurant. The transformation of home delivery into an IT-enabled generalized service is directly related to the rise of what was termed "the on-demand economy" in the late 2010s (this was also a part of what was euphemistically termed a "sharing economy") (Cockayne, 2016). The technology that enabled this delivery system was the smartphone so that those picking up and delivering the food could be connected digitally to those requesting the service (Reardon et al., 2021). Delivery workers were legally classified as independent contractors and thus did not need to be paid minimum wages or receive benefits (Shapiro, 2018; Milkman et al., 2021). As opposed to Uber, this type of service did not displace

workers. Rather, it created a new category of service worker that saved consumers the time necessary to go to the store or restaurant.

Delivery workers who worked in these on-demand apps worked under conditions almost identical to Uber and Lyft drivers. They have the freedom to choose their hours, though, of course, while working they were algorithmically directed and monitored. Their income, after car fuel and depreciation (which varies dramatically), often falls below minimum wage (among many reports, see, for example, Tingwall, 2020; Griesbach et al., 2019).

Increasingly, grocery stores that previously had their own employees pick the orders have created formal tie-ups with the delivery firms that have these gig workers pick the groceries for delivery, thereby outsourcing that work to the less expensive gig workers (Rivlin-Nadler, 2021). For example, Kroger has contracted with Instacart to provide the delivery service. In 2021, Instacart phased out 1,800 pickers that were Instacart employees inside stores—a decision that appears to have been driven by these employees voting to join a union. Roughly contemporaneously, Albertsons dismissed its employees that made the deliveries and replaced them with DoorDash contractors (Springer, 2021).

The rapid adoption of online shopping and delivery is impacting grocery employees, as delivery firms use gig workers to pick the groceries and thereby replace the grocer's employees. The final issue that will affect whether the delivery firms will have even greater impact is the question of profitability. At this time, the economics of these firms are roughly comparable to the transportation firms, such as Uber and Lyft, which are not yet profitable. Food delivery firms are losing money and none of these platform-based delivery firms were profitable in 2021. For example, in the first quarter of 2021, DoorDash lost $110 million on $1.077 billion in revenues. As is the case with Uber and Lyft, it can be argued that the delivery firms are disrupting current labor relations even though they are not profitable and

may never be profitable. We return to these delivery firms in the discussion of the impacts of the delivery firms on retailers and restaurants in the next section.

COVID and its associated lockdowns accelerated the movement online and this has significant impacts for the evolution of the relationship between consumers and their food providers. The first implication is that there may be a shift from in-store employees, who in traditional grocery chains have been unionized, to warehouse employment, which is often badly paid, grueling work. The second implication is that, increasingly, grocery stores may be disintermediated by warehouse direct delivery (by Amazon, for example) or by consumers purchasing directly from farmers. The possibility of direct sales by farmers could result in increased farm income—a socially desirable result. Of course, the other possibility is that Amazon, with its enormous buying power and sophisticated logistics network could, perhaps, with Walmart.com, weaken traditional retailers and absorb even greater market share.

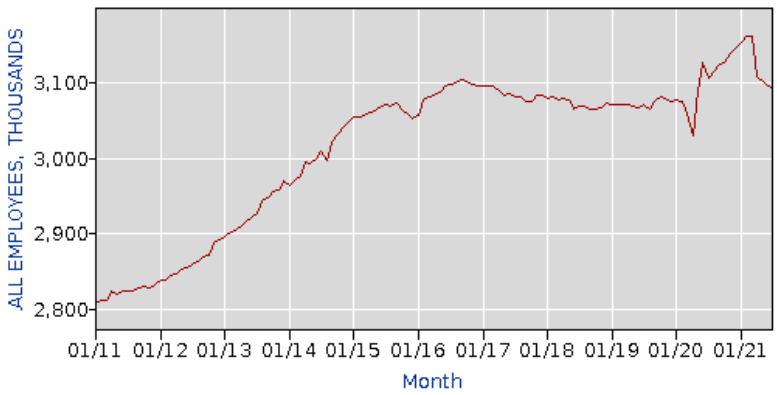
Moreover, there is the possibility of the development of a dual market structure, whereby on one side there are a few dominant online retailers that absorb greater market share at the expense of traditional supermarkets, thereby further hollowing out the middle market segment. On the other side, there would be large numbers of smaller platforms and vendors offering highly idiosyncratic, high-quality food products from local or specialty producers. For the smaller platforms and intermediaries, the question will be whether they can develop a sufficiently large customer base to cover their overhead costs.

3.1.3. Food Retailing

Food retailing is a vital service and, almost certainly, workers in indoor venues conducive to the spread of COVID were very much at risk of contracting the disease. As **Figure 2** shows, employment in food and beverage stores has been roughly stagnant since 2016 and then, in the COVID crisis, dipped slightly before recovering dramatically then

decreasing to the average since 2016. The growth in employment was, at least in part, due to the fact that lockdowns dramatically decreased restaurant traffic and thus redirected consumers to grocery stores. A US government report found that as of September 16, 2020, food and beverage in-store sales for the first 8 months of 2020 were up 12.2 percent compared to 2019, while food service and drinking establishment sales decreased by 20.9 (Dong & Zeballos, 2021). This reflects the massive shift in consumer behavior due to COVID. It was accompanied by an increase of 39% in online retail from the first quarter in 2020 to the first quarter in 2021 (US Census Bureau, 2021). These overall statistics indicate that the response to COVID and the lockdowns redirected labor in a number of ways. The most important of these was a shift away from eating out to in-home consumption and the adoption of online purchasing—a pattern that may not be reversed. While the first response may already be reversing, it is unclear whether this drop in employment is because stores have voluntarily decreased their employment or because employees found other employment or income sources and are no longer willing to work in this sector. In August 2021, the US Bureau of Labor Statistics (2021) reported the most job openings in history and this was reinforced by popular press reports of shortages.

Figure 2: Grocery, 2011-June 2021



Source: U.S. Bureau of Labor Statistics. (2021). *All employees, thousands, food and beverage stores, seasonally adjusted*.
https://data.bls.gov/timeseries/CES4244500001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

Food retailing has experienced significant digital advancement over the last four decades. Perhaps the greatest advance was the introduction of barcode scanners in the 1970s and its broad adoption in the 1980s that had automated and sped up checkout (Basker, 2015). With the barcode, products could be scanned and inventory and accounting simplified. Similarly, in restaurants, adoption of new technologies and software had steadily advanced, particularly in fast food chains where order-taking had become increasingly simplified through the use of point-of-sale terminals (POS). More recently, building upon the ubiquitous scanners, grocery stores had introduced self-checkout in a further effort to reduce labor costs. In summary, the focus of most automation in the last 20 years has been in the sales process, while the physical activities such as preparing and serving meals and stocking the shelves continued to be manual.

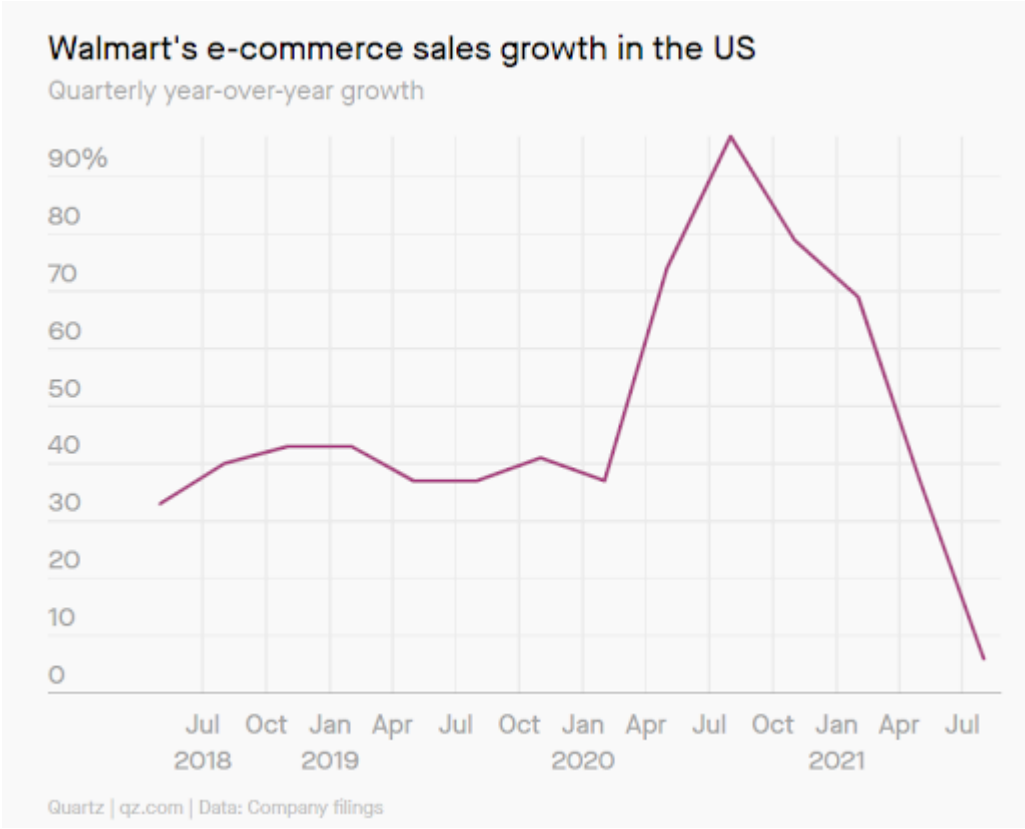
3.1.3.a Supermarket and Grocery Platformization

The widespread adoption of the internet permitted the emergence of new retail intermediaries; some of which operated as platforms, while others were online marketplaces (e.g., when Amazon sells products from its own inventory) (Hänninen et al., 2018). In some cases, this move to online sales was sparked by new entrants in this market over the last two decades, ranging from the online sales giant, Amazon, to specialized platforms for selling coffee, tea, and other handicraft foods. Similarly, incumbents such as Walmart and the various grocery stores that also moved their inventory online to meet the changing consumer habits.

Some of these online retailers have physical stores, while others are entirely virtual. The most notable new entrant is Amazon that, in addition to their physical stores (Whole Foods and Amazon Fresh), stocks and delivers groceries of all kinds, including fresh fruits,

vegetables, and meats. COVID was a powerful accelerant to the adoption of online grocery shopping. For example, in 2021, while still a small part of Amazon's overall business, it was estimated that Amazon sold $14.6 billion (while Walmart.com sold $10.1 billion) worth of groceries online—however total online sales remain only 10% or so of total grocery sales (Redman, 2021).[4] Nonetheless, the online sales growth rate is expected to be about 15% per year, which means that the proportion of in-store sales will decrease. Having said this, in 2021 customers appear to be returning to physical stores, as the slowing in the growth of online sales at Walmart appears to indicate in **Figure 3**.

FIGURE 3: Walmart's E-commerce Sales Growth in the US



Source: Bain 2021

[4] As a point of comparison, in China Alibaba sold $20.1 billion in groceries in 2021 (Redman, 2021). Redman, R. (2021, July 15). *Amazon to nearly double online edible grocery sales by 2026*. Supermarket News.https://www.supermarketnews.com/online-retail/amazon-nearly-double-online-edible-grocery-sales-2026

While the large firms such as Amazon and Walmart.com receive the greatest attention, there are a remarkable variety of other platforms and online marketplaces emerging that consumers can adopt (Oncini et al., 2020). These include platforms to connect consumers directly to farmers, thereby disintermediating all the middle organizations. Other platforms like Imperfect Foods, address food waste by selling online excess food that grocery stores do not buy from the wholesale markets. The sheer diversity of the entrants into food retail is remarkable. For example, in Italy alone, a study by Oncini et al. (2020, p.174) identified 180 online retail organizations selling from their own inventory (this inventory does not include firm websites for the direct sale of their own products) and another 31 that fit their strict definition of a platform. Because of the low cost of entry, there is remarkable diversity of business models; some of which are non-profit, thereby illustrating both goal diversity and a remarkable heterogeneity of organizations.

3.1.3.b Grocery Store Automation

The adoption of robots in grocery retail is underway. This can be divided into two general categories based on the context. The first context is within existing stores built for humans. Stores in the US and abroad employ mobile robots that move on a preset path searching for spills on the floor and either alert employees or, in more advanced versions, find and clean spills. Other robots have been introduced to scan shelves for out-of-stock products (Matthews, 2020). Despite the many articles that describe grocery stores experimenting with robots, there seem to be far fewer that have decided to equip all their stores with them.

The second context is the creation of micro-fulfillment centers in retail stores where robots directly pick groceries for delivery to consumers (McTaggart, 2021). In this model, part of the retailer's store is converted into a fulfillment center or a new facility is added to an existing facility, where the products can be arrayed in a way that is optimized for robots and the robots are separated from the public. The objective is to use the retailer's existing facilities

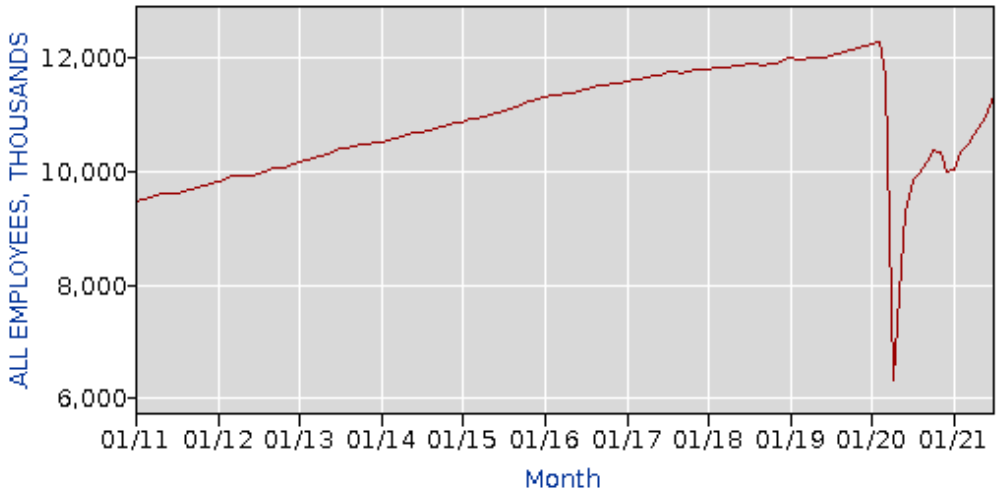
to allow rapid fulfillment of local customers' online orders. As is the case with most of the in-store robots, much of the activity continues to be experimentation and not full-fledged adoption.

Even as the impact of online platforms is threatening to reallocate labor away from bricks-and-mortar retail facilities, what is likely to remain the lingering impact of COVID is the widespread digitalization of processes that occur between the consumer and retailer. In addition, it may be the case that a persistent continuing trend in the digitalization of this part of the agrifood system may also generate different jobs. However, as research on gig work has largely shown, supermarkets and grocery store markets provide few long-term employment opportunities (Wells 2019).

3.1.4. Food and Drinking Establishments

Employing over 12 million persons before the pandemic, food and drinking establishments are one of the largest employers in the US. This work is often informal, highly variable, and badly paid. As **Figure 4** shows, the pandemic, with its associated lockdowns and other public health measures, was powerfully affected despite the various government programs that might mitigate the disaster.

Figure 4: Employment in Drinking and Food Establishments, 2011 to June 2021



Source: U.S. Bureau of Labor Statistics. (2021). *All employees, thousands, food services and drinking places, seasonally* adjusted. https://data.bls.gov/timeseries/CES7072200001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

In the US context, fast food restaurants can be understood as a Fordist initiative in providing for a society based on the private automobile and prepared food (Ritzer, 2000). The fast food model was the preparation of food in a factory for final preparation and delivery at scattered "restaurants" for consumption on the premises or through pick-up. The labor model was factory and truckers for delivery, and the bulk of the final production/service workers are low-paid, largely unskilled, part-time workers (Schlosser, 2012). In this respect, the automation of the production of meals has a long history. Of course, fast food was only one segment of the entire food industry.

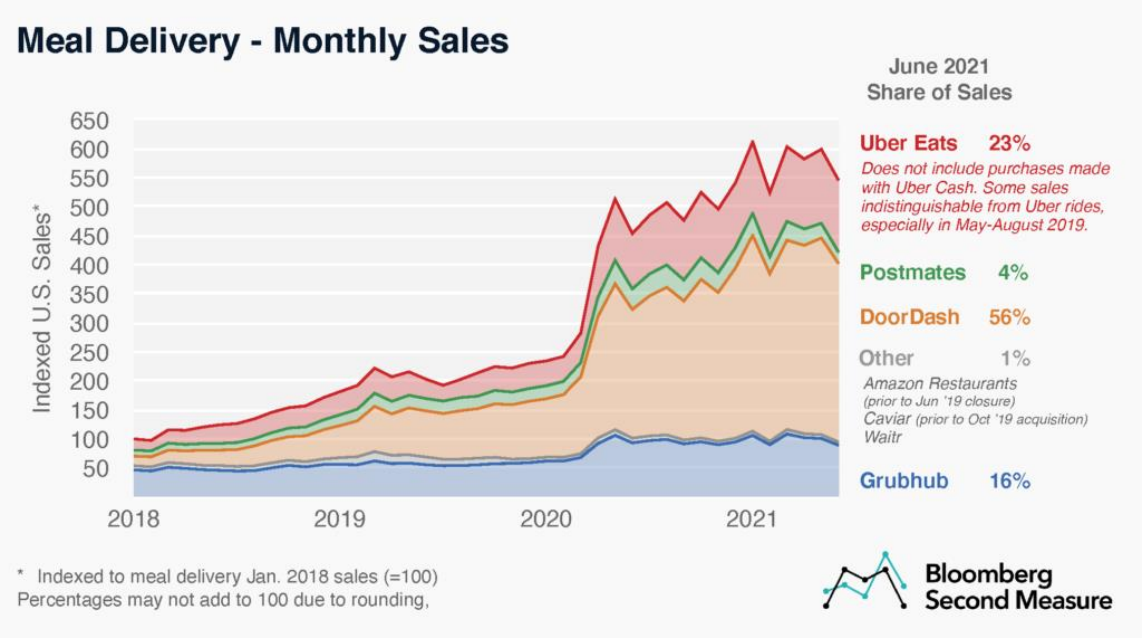
The entire restaurant industry has been increasingly automated in terms of using payment systems, microwaves etc. Though the typical restaurant was not nearly as automated as those in the fast food sector, all, of course, depend upon low-paid, often immigrant, labor in the kitchens.

The importance to online platforms in the restaurant industry was already becoming evident prior to the pandemic in the following ways: 1) restaurant review platforms such as Yelp and Google were affecting restaurant success and, 2) increasingly, restaurants felt compelled to advertise on these sites or suffer from significant losses of business (Luca & Zervas, 2016).[5] The ability of these review sites to pressure restaurants to pay for advertising is significant for labor because these restaurants employ significant numbers. However, many independent restaurants also employ family and friends, all of whom would experience losses were the restaurant to fail.

Even earlier than grocery store delivery, platforms such as DoorDash, GrubHub, Instacart, Deliveroo, etc. were delivering meals from restaurants to consumers. With the onset of COVID and accompanying lockdowns, these delivery platforms became vital intermediaries between the restaurants and consumers (see **Figure 5)**. The rapid growth of delivery platform intermediaries due to COVID19 is evident in the approximately $5.5 billion in combined revenue generated by the top US food-delivery platforms ---– Doordash, Uber Eats, Grubhub, and Postmates ---– throughout April-September 2020 (Sumagaysay, 2020). This increase contrasts starkly with the $2.5 billion in revenue generated by the four companies a year earlier (Sumagaysay, 2020). The pandemic generated need provided them with remarkable power over the restaurants and allowed them to dramatically increase the fees they charged the restaurant for leads and delivery. With the COVID pandemic and lockdowns, GrubHub and other delivery firms immediately increased the rates charged to restaurants to as high as 30% (Machi, 2021). Further, GrubHub was sued for charging surreptitious fees to restaurants for calls that did result in orders (Saxena, 2019).[6]

[5] Among small businesses the perception that Yelp is using unethical and potentially illegal tactics to extract profits from them is increasing (Harrison, 2019).
[6] More recently, a number of US cities have capped the fees these delivery services can charge restaurants at 15%.

Figure 5: Meal Delivery - Monthly Sales



Source: Perri 2021

These platforms intermediate between the restaurant and customers, and thus they are in a position to capture all of the value up until the point at which the restaurants no longer have any profit and are only able to survive, though for the platform even the restaurant's survival was largely irrelevant. Essentially, as Cutolo and Kenney (2020) describe, the restaurants had been converted into platform-dependent entrepreneurs—notice the restaurants were, in essence, compelled to join as their customers had joined. In 2021, cities across the US passed laws limiting the fees that the delivery firms could charge the restaurant, as the restaurant had no choice but to pay whatever the platform demanded. Here again, the impact upon labor is indirect, but, if the restaurant is squeezed, the expected knock-on effect is a squeeze on labor in terms of wages or hours. The other result is that more delivery drivers, all of whom are gig workers, will be "employed." Since this is entirely contingent work and, very often, results in income that is lower than minimum wage on a per hour basis, workers are

immiserated (see, for example, Payup, 2021)[7]. As the delivery workers are treated as independent contractors, their income is contingent upon the number of deliveries assigned and the time required to make a delivery. Finally, their income can be changed at the whim of the platform by algorithms that are only partially understood (see, also Cutolo & Kenney, 2020).[8]

3.1.4.a Ghost Kitchens

The final platform-related innovation that could have a significant impact upon food service labor is the emergence of "ghost kitchens", which is a term used for online orders to websites and restaurants that have no in-person service. The food is prepared in a kitchen (which can essentially be anywhere) and then delivered by courier to the customer. While experimentation with this production model was already underway prior to the pandemic, as meal delivery was already expanding rapidly (Reforming Retail, 2019), pandemic-related lockdowns meant that all restaurants, in essence, adopted the ghost kitchen model.

On the face of it, the ghost kitchen model offers remarkable efficiencies in the sense that servers, dishwashers, cashiers, hosts, and all other workers associated with the dining area are no longer required. This would also allow a reorganization of the kitchen, as there would no longer be need for space for servers and others to go in and out. Prior to the pandemic, some projections suggested 50% of meal spending could be satisfied by ghost kitchens; perhaps, after the pandemic ends, this could be even greater. In terms of employment, a massive number of workers and occupations could be permanently impacted.

There is no standard configuration for ghost kitchens. Essentially, they can be anywhere with any internal spatial configuration. For example, one model has been to

[7] It is difficult to calculate the per hour income of platform-mediated gig workers, but the general consensus is that, at best, it is little more than minimum wage (Payup, 2021).

[8] In 2020, DoorDash was discovered to have been keeping all or part of the tips that customers gave to the deliverers (Kelso, 2020).

configure an industrial space and place any number of cooking stations in them. Each cooking station could be its own "restaurant" with its own menu (Austin, 2021). They could share utilities or even labor such as pot washing, delivery docks, etc. In this model, because of the volume, it is also possible that robotization for larger common tasks could be introduced. Prior to the pandemic, the ability of platforms to insert themselves between meal providers and customers for in-person dining through online reviews and, later, through delivery apps from existing restaurants was already eroding the market share of in-person restaurants. This is not to suggest that in-person restaurants will disappear, but meal delivery is growing in terms of percentage of all purchased meals. There is one final caveat: namely, that, as in the case of grocery delivery and ride-hailing, these business models are not yet profitable and thus continue to be dependent upon capital infusions from investors.

3.1.6. Summary of Labor Issues in the Customer—Retail Relationship

The various platforms that have been organizing the relationship between the consumer and food providers are transforming the value chain, but also making it more algorithmically visible. If in-person purchasing is replaced by online sales and delivery, there will be a shift in labor toward direct delivery from warehouses, thereby displacing the already limited in-person relationships with consumers. This will have implications for workers as well as for automation and production processes across this node.

Perhaps the most important implication of the increased digitization of this node is the increasing visibility of the value chain. Such processes allow for deep retail insights and visibility across the value chain. This will make it easier to identify where breakdowns and/or errors occur across the value chain. For example, when food preparation errors lead to public health concerns, it is possible that the increased digital footprint allows for the swift identification of the possible origin and source of the concerns. Specific to the impact of

COVID, it is important to note that businesses and industries included in this node began repurposing existing AI applications and algorithms or created new ones to help employees adjust to new safety regulations and deployed remote real-time equipment monitoring for things such as safety zoning enforcement, social distance monitoring, PPE detection, contactless health screenings, and contract tracing. While increasing the digital footprint can improve visibility and accountability for the consumer, it does mean that there will be increased observation and monitoring of workers themselves. While this can support management practices and ensure compliance to mandates, the deployment of such technologies may have the capacity to stifle productivity as well as decrease overall satisfaction of employees, which could impact turnover and overall mobility within sectors.

3.2. Processing to Distribution/Warehouses

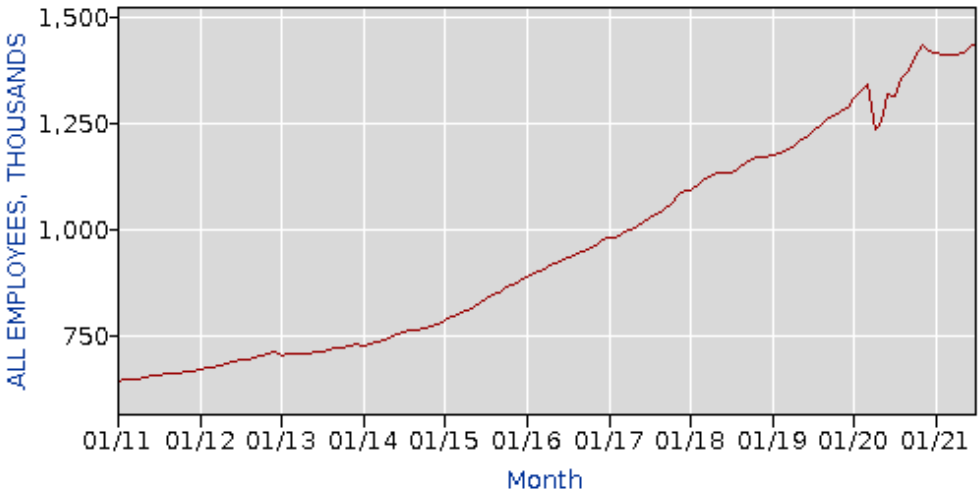
This segment of the value chain consists of the activities necessary to move raw agricultural products from the farm gate to the distributors. The key nodes are food processors, warehousing/distributors, and transportation providers. Perhaps, more than any other segment in the agrifood system, this has experienced significant investment in digitalization and robotization, particularly in warehousing. Food processing and, in particular, meatpacking, was one of the most dramatically affected industries, as the work is located inside buildings with workers tightly packed together on assembly lines in environments with high humidity and limited ventilation (Dollar & Steusse, 2020). In both warehousing and processing, pay is low, work is stressful, and sick leave is rarely offered except in the few plants that are unionized. While the number of employees in these operations vary, many of them employ hundreds or even thousands of employees.

3.2.1 Warehousing

The move to online purchasing dramatically increased employment in warehousing (as can be seen in **Figure 6)**. Of course, Amazon's massive build out of warehouses across the

country was a major factor in this growth in employment as it promised Amazon Prime members same-day delivery, which other retailers have had to match (on Amazon's warehouse growth see Kenney & Zysman, 2020). Food is only one component of the entire warehousing sector, and existing supermarkets and grocery stores already had their own warehouses. When Amazon entered fresh foods, it drew upon the Whole Foods warehouses, but also built new fulfillment centers for fresh foods (Newberg, 2020).

Figure 6: Warehousing and Storage Employment, 2011 to June 2021



Source: U.S. Bureau of Labor Statistics. (2021). *All employees, thousands, warehousing and storage, seasonally adjusted*. https://data.bls.gov/timeseries/CES4349300001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

As we began discussing in the previous section on retail, the movement of groceries online made it possible to disintermediate existing physical grocery stores. However, these stores were also in relatively close proximity to customers, thereby also making it possible to fulfill online orders from them. Here, Amazon would be able to use its Whole Foods and other physical stores to meet online orders.

The COVID crisis and enormous spike in online demand for groceries (and other products) led to a massive expansion in demand for warehouses and workers. Leading this expansion has been Amazon, which in 2020 added approximately 350,000 new warehouse and delivery workers. However, according to a *New York Times* investigation, Amazon experiences turnover of approximately 150% a year, which is approximately double that of the retail industry (Weise & Ashford, 2021). In many respects, Amazon is the leader in building warehouses, automation, and digital management. While it is unclear as to whether Amazon's treatment of its workers is exceptional in the industry, there is ample testimony from workers to suggest that the brutal conditions are programmed into the algorithms (Delfanti, 2021) that are constantly searching for ways to squeeze ever more value from the workers.[9] In the case of Amazon, in particular, all the workers' activities—productivity, attendance, time away from their workstation (for bathroom breaks), etc.—are monitored algorithmically[10] and for those that the software identifies as not meeting their goals, termination decisions are made algorithmically and communicated to the supervisors (Lecher, 2019).

Moreover, as workers become more proficient, the goals are increased and those unable to meet the new goals are terminated. Effectively, there is inexorable pressure to increase productivity and this pressure has led to extraordinary rates of injury—when they are reported (Ivanova, 2021). The workers and their bodies are treated as machines to be inexorably utilized to their maximum, but, most importantly, there is no commitment to their

[9] There are a number of reports suggesting that frequent turnover among fulfillment employees is an Amazon goal to keep wages low and ensure that they do not develop sufficient solidarity to, perhaps, organize unions (Weise & Ashford, 2021).

[10] It has also been reported that the algorithms make mistakes and the workers have difficulty getting the mistakes corrected. There is a distinct pattern of algorithmic mistakes across different firms that appear to favor the firm.

ability to reproduce themselves—it is more akin to strip-mining than cultivation. In such an environment, turnover is an acceptable cost as the workers are disposable cogs.

With this labor management stance, Amazon's reaction to COVID was predictable. Given the size and number of workers, fulfillment centers experienced significant outbreaks of COVID, though Amazon did not report cases to either the authorities or their own employees (Hussain, 2021; Weise & Ashford, 2021). COVID, for Amazon, was simply a cost of doing business. Fulfillment center automation was already underway prior to COVID, and advances in technology and particularly robots able to pick and place has been rapid and, increasingly, warehouses for all products are being automated.

3.2.1.a Warehouse Automation

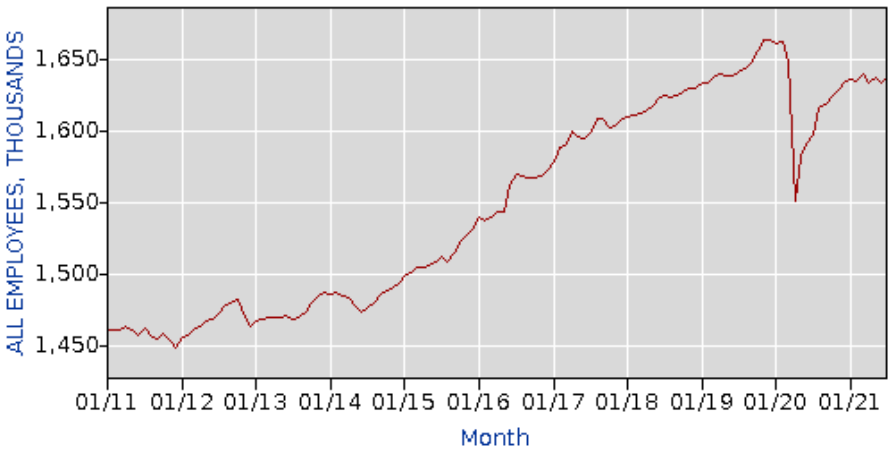
Automation and digitalization have been transforming warehousing and, undoubtedly, Amazon has been the leader in this process as it integrated back into fulfillment (even this new term suggests that the product is being pulled by the consumer). The ability for computers to record where every item is has changed the warehouse profoundly, moving it from one where worker knowledge is important to one where it is unimportant. Consider the most basic decision, which is where to place products. In the traditional warehouse, products were grouped together—toothpaste was in the toothpaste section and hammers were in the hammer section. However, Amazon, perhaps drawing upon data storage principles, places products randomly throughout the warehouse (Marshall, 2020). This makes finding items entirely dependent upon the computer which records where each item is located. This saves space and permits the warehouse to house many more stock keeping units (SKUs). For example, a new warehouse opened in 2019 in New Haven, CT could manage one million+ SKUs (Trebilcock, 2020) and employ 2,500 workers. Counter-intuitively, randomization reduces travel time to pick the item, as the computer can compute the shortest time between a

picker and an item of the product. However, the impact of this decision is far more profound. If workers do the picking, then they do not need to "know" where things are; in fact, they cannot know where they are (Delfanti, 2021). In previous iterations, workers walked through the factory picking; now, the transport robots bring a shelf with the items to stations where the worker does the picking—a job that requires manual dexterity but little knowledge. This Braverman-like deskilling means that there is little value in knowledge-based seniority—something recognized by Amazon as the turnover churn continues to increase.

3.2.2. Food Processing

The food processing (manufacturing) industry was impacted by the pandemic, but it was quickly designated as an essential industry, which meant that their facilities were not closed during lockdowns (Artiga & Rae, 2020). As **Figure 7** indicates, employment in the industry plummeted as the consumption collapsed, but then bounced back rapidly. Workers in meatpacking, in particular, driven by the working environment being extremely conducive for virus transmission, suffered many cases of COVID and a number of deaths (Taylor et al., 2020). Despite being exempted from mandatory lockdowns, many food processing facilities announced localized lockdowns due to massive outbreaks. Yet, despite the lack of generalized shutdowns, employment still remains significantly lower than the 2019 peak, and the food processing and, particularly, meatpacking industry now suffer from significant labor shortages (Doering, 2021).

Figure 7: Food Manufacturing



Source: U.S. Bureau of Labor Statistics. (2021). *All employees, thousands, food manufacturing, seasonally adjusted*. https://data.bls.gov/timeseries/CES3231100001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

The COVID pandemic hit meatpacking plants particularly hard. From April to May 2020, more than 17,300 meat and poultry processing workers in 29 states were infected and 91 died (Bunge & Newman, 2020). It is not surprising that "meat processing facilities [would be] particularly vulnerable to COVID-19 because of the high density of workers required for operations, prolonged close contact of personnel on the production line, indoor work environments with compact cafeteria and locker room areas, and a workforce with diverse cultural and linguistic backgrounds that make educational efforts more challenging" (Herstein et al., 2021: 1032). Meat processing has always been one of the most dangerous occupations in the US and has employed a largely low-paid migrant workforce for the last 100 years (see Upton Sinclair's *The Jungle*) (Leibler & Perry, 2017).[11] Animal carcass disassembly lines in the US remain crowded and largely without a significant level of

[11] For a popular press discussion, see Lopez, R. (2020, May 12). Meatpacking has long been dangerous, grueling work. Then COVID-19 hit. *Minnesota Reformer*. https://minnesotareformer.com/2020/05/12/meatpacking-has-long-been-dangerous-grueling-work-then-COVID-19-hit/

automation (it is automated in the sense that it is a moving assembly line, but humans continue to do the bulk of the physical work).[12] In contrast, countries such as Denmark have a highly automated meat packing industry and were reported to have far fewer COVID cases, as of 2020, than those in the US (Molteni, 2020).[13] What is certain is that, in the US, the need to close meat packing plants due to the COVID outbreaks and increasing labor shortages that existed prior to the COVID pandemic have increased interest in automation (Molteni, 2020).

Given the conditions in the US meat packing industry, labor shortages were already a problem and the firms were already investing in automation. For example, from 2017, Tyson Foods, producer of roughly 20 percent of US produced chicken, beef, and pork, invested more than $500 million in automation and related technological advancements (Bunge and Newman, 2020). Yet, in meatpacking, perhaps more than many other industries, automation and robotization is replete with a remarkable number of contradictions only exacerbated by the pandemic. First, the work is repetitive, fast-paced, dirty, dehumanizing, and dangerous. For this reason—the degradation of work and the workers and the low pay—there have been persistent labor shortages. In this respect, automation offers the possibility of making the workplace more humane (as humane as slaughtering living beings on an industrial scale can be). Second, while automation should make the work process more humane, it also has the potential to replace workers for whom there are few alternatives. While management suggests that the remaining workers can be moved to less stressful jobs minding, guiding, and, perhaps, even repairing the robots, there is no guarantee that the meatpacking workers whose activities are replaced will be those retrained. Third, the increased capital intensity

[12] Interestingly, Henry Ford got the inspiration for the moving assembly line from Swift's carcass disassembly line in Chicago and adapted it for his assembly line (Fields, 2004). However, in contrast to automobile production, which today is highly robotized, carcass disassembly remains far less automated. Of course, this is, in part, due to the lack of uniformity in an animal carcass when compared to an automobile. Thus, the process, while standardized, deals with a slightly less predictable object of work, thereby requiring the subtle adjustments that humans can make with ease, but machines need to be programmed to take into account (Desmond, 2020).
[13] The Danish operations were not completely without having COVID problems, as one Danish slaughterhouse had to be closed for a week due to it becoming a major COVID cluster (McCarthy 2020).

might operate to increase concentration in the industry, thereby decreasing competition. Thus, meatpacking, in particular, was affected by COVID very early in the pandemic and the expectation is that, in response, there will be increased deployment of automation, though the resulting impact on labor is difficult to predict.

The severe COVID outbreaks in meatpacking received the greatest attention in the press, and yet, other food processing facilities were also impacted by the pandemic, shutdowns, and an increasing labor shortage. Initially, the pandemic sparked mass hoarding. This was followed by plant shutdowns, of which there were many, but the problems were less acute than in meatpacking—likely in part due to the fact the work is in a severe environment less conducive to the spread of pathogens and automation was already more advanced and thus, in general, workers were not working as closely together. These developments meant that the food processing industry did not throttle back production as much as other industries that experienced dramatic drops in demand (see **Figure 7 Food Mfg**.).

One outcome of the pandemic is that an increased percentage of groceries were sold through platforms, in particular Amazon, which with its enormous volume was able to force food processing companies to provide discounts that often are even larger than those demanded by the large grocery chains. However, this may be offset by the potential for food processors with established brands or even for white-label food producers to create "brands" and to sell directly to the consumer, either through Amazon or their own websites, thereby disintermediating retailers. In the case of selling through Amazon, of course, they are then subject to its whims. All of these alternative channels could have impacts on workers who are employed by these firms.

3.2.2.a - *Summary of Labor Impacts in the Food Processing/Distribution to Retail Relationship*

Automation in both production and distribution adopted during and due to COVID and the possibility of developing new channels to sell directly to consumers pose some rather ambiguous implications for labor. While automation and other measures, such as social distancing, may have been adopted primarily due to workplace public health concerns, the automation will have longer-term impacts. While pre-pandemic adoption was driven by the desire for productivity improvements, the pandemic and resulting labor shortage meant that further innovation to repurpose or develop new technologies were, in part, driven by safety concerns. Whether those adopted simply for public health concerns will continue after the pandemic ends is uncertain. The multivalent nature of many of these innovations can be illustrated by Amazon AWS Panorama, a smart lens camera system that was built to allow the deployment of computer vision-based applications. The system is used to automate both monitoring and the visual inspection tasks traditionally performed by humans. Designed to improve warehouse and manufacturing quality control, it can also contribute to workplace safety (Humphries, 2020).

However, the longer-term implications for labor presented by increasing automation and digitization in agrifood processing and distribution systems are uncertain. While many of the rapid innovations seen above were pivoted to support public health in the workplace, it is possible that these will not outlast the pandemic. However, such automation may also contribute to improved health and worker safety, as was the case with the highly automated Danish slaughterhouses that also experienced fewer COVID outbreaks.

From a labor process standpoint, the increased automation is likely to result in greater deskilling and replacement of workers, though it is also possible that it could augment the

worker skills.[14] The way businesses decide to redesign future work processes around these technologies will determine the extent to which the implications for workers are transient or permanent. While increasing adoption of robots and automation is underway, workers will still work alongside robots—albeit, perhaps, in a more precarious position in terms of replaceability. That is, the robots work by increasing efficiency and productivity and thus do not appear to be poised to immediately replace workers. Yet, these technologies will result in a redesign of labor processes. What is clear is that it is unlikely that production processes in both processing and distribution will return to the status quo ante.

3.3 Farming to Processing

This node concerns the farming and transportation to food processing, distribution, and the consumer. On the farm, use of computers and automation is increasing steadily. In this paper, we do not discuss this process except as a background for discussing the impacts of COVID. For discussion purposes, it is useful to separate family farming and the large-scale farming that uses large numbers of farm workers in the fields and packing sheds. In the US, family farmers are heavily represented in row crops such as corn, wheat, soybeans, and cotton as well as in dairy farming, though dairying is increasingly automated and using more farm labor.

It is important to consider the changing context for farmers. The equipment they are using is increasingly digitally enabled and has led to the rise of what has been termed "precision agriculture" or, more recently, "smart farming" (Carolan 2017; Klerxx et al. 2019) The improving functionality of sensors and software enable the increasing automation of agricultural equipment that has defined farming to warehouse processes in the food system

[14] The deskilling debate, first given prominence by Harry Braverman (1974). It should be recognized that Braverman focused on the individual worker, while, from the perspective, of the entire society, due to the division of labor it is possible to argue that the skills of the "collective worker" have increased, despite the fact that skills embodied in any one individual have decreased (Adler, 1990). Clearly, this debate could be continued to the contemporary wave of automation.

has included: the introduction of in-field and remote sensors for moisture, nitrogen, soil, and air temperature; capturing animal vital signs in real time; monitoring myriad other environmental variables; and GPS. For example, sensors, both in the field and remote, and the increased capability of farm equipment to variably apply fertilizers, pesticides, and seeds, are improving the efficiency and efficacy of inputs and thus limiting their impact on the environment (Revich et al., 2016). Grain harvesters can measure the yield, protein, moisture content, and even the amount of impurities in real time and in an exact location in the field. With this shift to software for collection, measurement, and decision making—and given the fluidity of data—power could shift to the organizations that are capable of extracting value from the data (Miles 2019).

Small and medium-sized family farms in the US have faced low market prices for the last decade and COVID exacerbated pricing pressure, even as prices for consumers increased (Johansson, 2021). In terms of income, COVID had a negative impact upon farmers, particularly those producing row crops. The disruptions in the supply chain meant that food processors bought less of the farmers' output, leading to lower prices even when there appeared to be shortages and food price increases. The advantage for row crop producers is that they were not dependent on hiring or contracting for labor and thus the labor shortage had a lesser effect upon them. For these farms, the COVID pandemic does not appear to have significantly affected operations, though it certainly affected profitability.

For farmers producing fresh fruits and vegetables, there is less automation than in row crops. To illustrate, the automation of tomato harvesting is for industrial processing into tomato paste—not for table tomatoes. For these farmers, the impact of COVID has been more noticeable as harvesting in particular requires securing comparatively large crews that work collectively in the field, and thus are more susceptible to COVID transmission (Lusk & Chandra, 2021). The relative lack of automation is due to the fact that, for the most part, the

markets for each of these crops is relatively small. Moreover, the table market requires that the product be sufficiently ripe to be sold in supermarkets. Despite these caveats, automation is progressing as the digital technologies improve in terms of both image recognition and the ability of robots to handle delicate items. The COVID-related decrease in labor supply is exacerbating the pre-existing labor shortages that were already increasing the pressure for automation (Ridley & Devadoss, 2021). Given the labor shortages and relatively strict labor laws in the US (and particularly in the largest producer of specialty crops, California), the pressure for automation was already strong, and COVID has increased this demand (Taylor 2017).

The final large area of agriculture is animal husbandry. Automation and sophisticated monitoring are being applied to each activity from raising animals for meat to milk and egg production. As a generalization, all animal husbandry areas have been facing labor shortages, as work in these sectors is not well-paid nor desirable. In these sectors, COVID exacerbated labor shortages, while also disrupting supply chains and consumption. Large dairies are already highly automated with robotic milking machines, feeders, and floor cleaning. The machines also collect information on the cow's health. In poultry farming, automated systems are being introduced to control the climate in the poultry houses and the feed the chickens receive. This permits monitoring the individual birds and improves the ability to predict their health and analyze changes in their habits. As was the case with the other two areas of farming, digitalization and automation has been increasing. As in the rest of the value chain, in animal husbandry the use of automation and other information technologies had already been increasing and the pandemic has shifted the cost-benefit calculation toward yet greater adoption.

3.3.1 *Online Platforms and Direct Consumer Marketing*

Direct-to-consumer marketing, of course, was already significant for specialty crops—wine in particular, but also cheese and other processed products. Farmers markets and roadside marketing also offered farmers opportunities to sell their products directly to customers (Thilmany et al., 2021). Unsurprisingly, the advent of e-commerce provided a new sales channel for selling agricultural products. The possibility of farmers using their own websites or online platforms to connect directly with the consumers interested in purchasing their food online for delivery provided an important new channel for farmers. Given this opportunity, in the US, a remarkable number of sales platforms emerged to connect farmers to (often local) consumers (Frenay, 2019). Anecdotal evidence from Thilmany (2021, p. 98) suggests that between April and May 2020, online local food sales:

> "increased by 360% due both to increases in the number of orders (+189%) and dollars spent per order (+71%). As indicated by one respondent, a consumer may have only spent $10 to $20 per transaction at a farmers' market, but he or she now spends $75 to $100 in online transactions—a marked increase in basket size."

As is the case with online grocery shopping, where online shopping has decreased as concerns about the pandemic lessened, the question of whether online shopping for food direct from local farmers will continue to increase is uncertain.

While e-commerce grocery sales appear to be decreasing in the US, a very different dynamic is taking place in China. By far, the world's largest direct-to-consumer farm sales platform is the Chinese firm, Pinduoduo, which in 2020 served 12 million farmers and 800 million customers that it connected over its platform (Mullin, 2021). In 2019, the gross merchandise value (GMV) of (nearly all agricultural) products that were transacted over its platform was $45 billion, and it aimed to increase its GMV to $250 billion in 2025 (Liao,

2020).[15] Pinduoduo is building an entire fulfillment system to deliver products from the farmer to the urban consumer. Of course, China is the world's leading e-commerce market, thus it is difficult to generalize from events there to the rest of the world.

3.3.2 - *Labor Impacts in the Farming*

In examining the impact of COVID on the automation and digitization trends in this node of the agrifood system, it is clear that COVID had a minor impact on this node. Rather, the implication presented for labor engaged in this segment of the agrifood system is that COVID may have highlighted the vulnerability of this segment to labor shortages. Challenges here remain a lack of adequate human labor, which may have spurred more farmers to adopt platforms that can help link farms directly to consumers—particularly with the lack of transportation workers. At the same time, the rapid computerization and increasing digitization of processes will require that the workforce in this node of the agrifood system be more aware of digital technologies and computer systems generally.

The trends, in regards to digitization and adoption of AgTech on-farm, appear to be motivated more by the increased labor shortages induced by the pandemic than issues such as health and safety. Questions about whether the processes of increased digitization and increased automation in general would deskill, augment, or even require more training for workers were also commonplace prior to COVID. In terms of work processes, Mateescu and Elish (2018, p. 5) found that data-intensive technologies, such as crop management tools and "smart" tractors, require new work routines and changes in physical infrastructure, such as securing rural broadband internet and reorganizing the layout of barns or fields to facilitate

[15] While Pinduoduo does not release gross merchandise value in its stockholder reports, its revenues from the second quarter 2020 to the second quarter of 2021 grew 89% suggesting that it could indeed meet that target.

optimal sensor readings. In addition, cultural shifts in the business logics of family-owned farms may also be necessary as data-intensive agriculture advances.

The development of smart farms could upset the familial balance that characterizes the US "family-farm" model of farming. In the former structure of the family-farm "the farm business and farm household were viewed as one-and-the-same economic unit, as production and consumption decisions were integrally intertwined" (Sykuta, 2016, p. 63). The increasing automation of farm activities makes it possible to decrease the importance of the family in managing the farm's productive activities, thereby changing the farm's dynamics.

It is possible that, if current trends continue, the displacement of farm labor could be significant (Rotz et al., 2019), and the pandemic certainly may have accelerated this existing trend. While there has been little research in the US, the impact of COVID on the automation and digitalization trends on the farmers and farms would appear to be minor at this point—a conclusion that European research confirms (Meuwissen et al., 2021). Thus, AgTech adoption may be somewhat accelerated, however the difficulty in automating certain tasks, the high capital equipment costs, and the relatively difficult economic circumstances of many farmers suggest the increase in the speed of adoption will be moderate.

The greatest changes could be in the willingness of consumers to contract directly with farmers for food delivery over either new platforms or existing ones, which would reproduce Pinduoduo's success in China, to disintermediate the distributors and retailers (Mullin, 2021). At this time, in terms of farm production systems, it is difficult to conclude that COVID has led to any dramatic changes. However, if the current acute labor shortage continues, driving up wages or continuing harvesting problems, then automation will almost certainly increase. Finally, there is the possibility of entirely new direct-to-consumer sales platforms, which could change agricultural production as the demands of intermediaries such as retailers and distributors regarding product specifications would disappear, offering the potential for far

greater differentiation (organic, low food miles, traditional varieties, more geographical indications, etc.). This could, in turn, motivate different cultivation practices and thus labor practices.

3.4. Agroinputs to Farming

This node is focused on input suppliers and activities that are needed to ensure farmers can produce crops. This is an enormous and polyglot group that includes farm equipment manufacturers, agrochemicals, seeds, and a myriad of other producers. One important new group that can be added are software and data providers and consultants of various types. In the current food regime, a farmer purchases inputs, many of which are produced by highly oligopolized producers, from local distributors that also provide advice on usage. More recently, these input providers have also introduced mechanisms and contractual clauses requiring or inducing farmers to transmit various types of data back to the producers (Kenney et al. 2020).

In addition to the incumbent agroinput providers, there have been startups such as the Farmers Business Network attempting to create supply platforms for farm inputs (Kenney et al. 2020). What these platforms are attempting to do is disintermediate the local distributors, though they appear to have had limited success. While one might have expected the pandemic to accelerate such a shift, there does not seem to have been a shift toward purchasing inputs through a platform (RaboResearch, 2020).

A relatively new and growing group of input suppliers are data vendors that provide weather, remote sensing, pricing, and other types of data. While little has been written about this vast ecosystem of data suppliers, aggregators, and analysts, the increasing datafication of the farming already underway prior to the pandemic might have increased their importance; though at present there is little evidence that their prevalence or impact has been significantly affected by the pandemic beyond, perhaps, localized labor and parts shortages, both at the

local distributors and possibly at non-unionized, low-paying factories. This part of the entire supply chain appears to have been relatively resilient. The predominant changes in labor appears to be an increase in consultants and analysts that farmers must contract for the efficient operation of their increasingly complex and sophisticated farming equipment and operations (Kenney et al., 2020).

4. Systemic Impacts

The responses to the covid crisis and their impact on labor can only be understood in the context of tendencies that were already underway in the larger society and agrifood system (on the importance of the context for innovation, see Autio et al., 2014). As a generalization, the pandemic operated more as an accelerant for many business models that were already present. Many of these business models, such as ghost kitchens and grocery delivery, were being gradually adopted. The decision to lockdown entire sectors of the economy and the concomitant shift to online social and economic activity led to mass adoption of practices that previously were only slightly used. Of course, the rapid and widespread adoption of digital intermediaries and digitally enabled and monitored work processes (such as online food delivery) not only enabled activities and contributed to efficiency, it also meant that ever more data was generated and thus available for analysis and optimization.

Because of digitalization, the supply chain is becoming increasingly transparent, thus increasing visibility and traceability—a technological affordance that allows increased and increasing monitoring not only of objects, but also workers throughout the entire value chain. Having reviewed the associated activities across the main nodes of the agrifood system and the impacts of the COVID pandemic on each, it is clear that, as with other elements of the US economy and social life, the agrifood system was impacted by COVID. And yet, at each node the significance of the impacts differed. In some cases, the impacts appear to be largely

transient with minimal effect on the overall digitalization trends observed prior to the pandemic. In other parts of the value chain, the pandemic resulted in dramatic increases in the adoption of new digital technologies. One very important caveat is that the pandemic appears to have resulted in a noticeable and possibly long-term labor shortage throughout the value chain. Should this continue, it is almost certain to encourage an acceleration in labor-saving automation. This will also lead to displacement of existing workers, many of whom will be least advantaged in US society and thus least able to find other employment opportunities.

As we have observed, the impact of the pandemic will differ by the activities at each major node in the agrifood system. In **Table 1,** we summarize the impact COVID is expected to have on labor and automation at that node. As a generalization, we observe that the impacts of COVID on the interplay between digitalization and employment decline as one moves upstream in the agrifood system.

Table 1: Summary of Systemic Effects of COVID on the Trends in US agrifood System Digitalization and Automation by Node

Node in agrifood Value Chain	Digital Technologies	Impact of COVID on Existing Trends in Digitalization
Final Consumer	• **Smartphones**	**Powerful**
Retail	• **Online Ordering (Platformization)** • **Store Automation/ Micro fulfillment**	**Powerful**
Restaurant	• **Online Ordering (Platformization)** • **Ghost Kitchens** • **Quick Response "QR" Code**	**Powerful**
Food Processing (including meatpacking)	• **Process Robotization**	**Powerful**

Distribution/Warehouse	• **Robotization** • **Direct to consumer fulfillment**	**Strong**
Farm	• **Linkage to consumers through platforms** • **Cloud data sharing**	**Mild**
Agroinputs	• **Increasing digitalization** • **Data acquisition from farmers**	**Slight**

The most direct and powerful impacts were in the retail and restaurant nodes and their relationship with the consumer. The increase in home delivery of groceries and prepared food through delivery platforms, the emergence of ghost kitchens, entrance of Amazon into grocery sales, and severe labor shortages confirms the powerful impact that the pandemic has had and suggests that the reorganization in this sector will continue even after the pandemic abates. It is certain that there will be greater automation, however it does not appear that the entire structure of the sector will be overturned as is happening in the retail and restaurant nodes. In the case of warehousing and distribution, not only were there shutdowns, but also massive increases in demand as consumption patterns shifted to online and, particularly, Amazon expanded its food business. If grocery and foods sales continue to shift online, grocery stores will find it increasingly difficult to compete with online retailers. Further, Amazon and other food retailers are rapidly building ever more highly automated warehouses that will employ fewer and fewer workers per order fulfilled.

In contrast to the previous segments, food processing, and particularly meatpacking, had serious pandemic outbreaks that disrupted operations and led to numerous deaths. Automation was already prevalent in many European slaughterhouses. In contrast, in the

US, the carcass disassembly operations were still largely manual, though investment in automation was increasing. It is likely that the pandemic and the labor shortages will increase automation in the future. Automation is also progressing across the board in farming. However, there is little evidence that the pandemic has had a significant impact on farming in terms of disruption. The possible exception is in fresh fruits and vegetables that depended upon hand-harvesting, where the labor shortages caused by COVID exacerbated the existing difficulties in securing workforces that were observed prior to the pandemic. While it is possible that COVID has promoted the adoption of new technologies and processes, the technical difficulties and economic costs of automation cannot be overcome so rapidly. In other words, for those crops that were not easily automated, such as berry and fruit harvesting, there were no off-the-shelf technologies merely waiting to be adopted. The one possible change is the introduction of platforms that would allow farmers to sell directly to consumers.

The agroinput industries are already extremely capital-intensive and thus experienced little change due to the pandemic. The agricultural equipment industry did experience some COVID-related closures (Singh, 2020), but the greatest disruptions were experienced due to supply chain issues, for which COVID was partially responsible (Singh, 2021).

4. Potential Impacts of COVID on General Labor Conditions in agrifood System

Labor conditions and wages in the agrifood system vary by location in the value chain, skills, etc. As a general rule, farm, restaurant, and retail workers are paid badly and suffer from precarious employment with few benefits and high turnover. Conditions for employees in the food processing industries vary, but in slaughterhouses and vegetable packing, employment is largely of immigrants in crowded and unhygienic working conditions. All of

these industries have been highly dependent upon a low wage migrant workforce, many of whom are undocumented. Immigration flows across the US border were limited during the pandemic. Moreover, prior to the pandemic, there were labor shortages throughout the agrifood system due to a variety of factors including stricter immigration for legal and illegal enforcement, better wages in cities and other industries, and the desire of agricultural workers' children to seek jobs in better-paying, more stable industries.[16]

Accelerating trends in automation and digitalization in the agrifood system were already documented and found to affect work processes prior to COVID. Studies found that the need for on-farm labor was beginning to decline and some suggested that the replacement of new technologies would replace some tasks and jobs while creating others. It has been estimated by the Bureau of Labor Statistics that in nine years, there will be more than 5.35 million jobs available in the agrifood system if current trends continue. At the same time, questions about whether or not labor would be impacted by such trends remains common in scholarly literature and policy discourse. While the impact of COVID remains unclear, scholarship prior to the pandemic suggested that, in agriculture specifically, while the on-farm workforce was likely to experience a low level of displacement, many others in the food system such as operators of food cooking equipment, fast food cooks, and farm labor would have a higher risk of displacement (Frey and Osborne, 2017).

The ultimate impact of automation and digitization processes on employment is indeterminate, particularly in the wake of COVID. Here, some insight can be gained from conjectures based on previous trends. For example, if drivers are replaced by automated tractors, would the demand for agricultural software developers outnumber the displacement of farm labor? Of course, the new workers could be from an entirely different labor pool. The

[16] This is widely described in the popular press, see, for example, Rosenblatt (2021).

introduction of tractors in US agriculture in the 1920s to the 1940s led to farm consolidation and displacement of massive numbers of agricultural workers (Kenney et al., 1989). Instead of remaining in agriculture, these workers moved to cities to work in factories. Yet, until we observe the extent to which automation and digitization are integrated into the new normal of labor processes across the agrifood system that extends beyond the immediate impact of COVID, the possibilities are significantly varied.

Conclusion

The pandemic was and continues to be traumatic for the US economy and society, which had among the highest death rates per million in the world. When one considers the agrifood value chain from farmworkers and food processing to restaurants, retail, and delivery, the direct workers experience among the lowest wages and least benefits of anyone in society. Moreover, workers in nodes such as food processing and warehousing had among the highest incidences and death rates in the country. It is little wonder that, given the generous government benefits, many of these employees are not returning to work, thereby triggering labor shortages. Automation is a predictable response to these conditions.

The increased digitalization of the agrifood system makes it possible to collect data at every node, increasing not only traceability, but also the ability to monitor workers and presumably wring more productivity out of them, thereby reducing the need for workers. Amazon, in its fulfillment operations, takes the algorithmic management of labor to new extremes. Given the delivery platforms and Amazon developing its own fulfillment operations, the ability to monitor and control labor is remarkable as all movements can be analyzed and optimized, presumably to decrease the cost and labor content of every order fulfilled, thereby maximizing efficiency.

At the macro level, important questions are emerging, such as how all the data produced from an increasingly digitized system will be organized, who will own it, will

online platforms or data interchange standards be adopted and who will capture the benefits? At each node in the system, questions exist as to who owns the data and how access and the ability to analyze data could transform power relationships, worker and farmer skill requirements, and other matters. How much the pandemic will reship the course of adoption and implementation of digitalization in its manifold manifestations in agriculture.

While the discussion presented here is focused centrally upon labor and nodes in the agrifood system, it is important to note that online platform firms such as Amazon and the food delivery firms in the US and firms such as Pinduoduo are providing new ways for farmers to differentiate themselves and connect directly to consumers, even as they dramatically weaken other firms in the system. To illustrate, Pinduoduo has become so powerful that it offers farmer assistance services to make their products and themselves more attractive to final consumers. Platformization could provide farmers with new sources of income, even as success using the platform can make the farmer dependent upon it. It is incontrovertible that the lockdown response to the pandemic allowed these platform firms to deepen their intermediary status in the post farm gate segments of the agrifood system. More research on platforms in agriculture is important not only for academics but also for policymakers.

To fully extract the potential benefits from the digitalization of the agrifood system, ways of sharing data that do not disadvantage any of the parties is of vital importance. Existing actors and new entrants into the agrifood system will have to develop business models that enable data sharing. The owner of the platform is likely to develop inordinate power when compared with the other actors in the system. And yet, the structure and even number of platforms that will survive or come to dominate remains unknown. Ideally, the platforms that succeed will aggregate data so that its value can be exploited, while ensuring

that the data providers are compensated and assured that data will not be used in ways that are inimical to their interests.

In conclusion, the pandemic was a powerful shock to the agrifood system and the dynamics of inter firm competition, the relationship between firms and labor, and consumption. When the pandemic ends, some of these changes are likely to be permanent, while others are likely to revert to the status quo before the pandemic. One of the largest question marks is whether labor shortages will continue as supplemental unemployment benefits, other social welfare spending, and lockdowns ease in order to revert to circumstances which may make it easier for workers to return to work. Should labor costs revert to the status quo and ample supplies become available, the pressure to automate might be mitigated. Yet, the declining cost of computing power, the improvements in software, image recognition, and robotics will certainly lead to further improvements in automation and, most probably, labor displacement. If these come to pass, they will demand significant investment from a workforce development and social welfare standpoint.

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