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ABSTRACT

Purpose: Some of the biggest economic disruptions from the COVID-19 pandemic were experienced in food supply chains, particularly in the protein sector. This article examines these protein-sector supply-chain shocks, exploring the nature and causes of the market disruptions during the pandemic, evaluating the effects of these shocks from an economic perspective, and discussing potential market and policy responses that could mitigate the adverse effects of similar events in the future.

Sources: A variety of sources contemporary to the pandemic were surveyed to document pandemic effects on meat and poultry supply chains. The implications of pandemic effects for supply chain participants were explored, drawing from sources in supply chain management, network reliability, and agricultural economics literature.

Synthesis: Pandemic-related disruptions to meat supply chains and the economic hardship associated with those disruptions have generated tremendous interest in improving supply chain robustness and resilience. Much of that interest focuses on encouraging local and regional processing operations, creating shorter supply chains. At the same time, commercial interests will most likely aggressively pursue further automation to mitigate the effects of labor supply disruption—their major problem during the pandemic.

Conclusions and Applications: Local and regional processing operations are receiving a significant infusion of pandemic relief funds. Consumers are currently keenly interested in local and regional food options. At the same time, commercial operations will likely become even more efficient due to postpandemic adjustments. Thus, local and regional operations may face an even more challenging competitive environment than before the pandemic.

Key words: economies of size, food demand, local food systems, resilience

INTRODUCTION

On January 4, 2020, the World Health Organization announced that the government of China had, a few days prior, reported a cluster of pneumonia cases in the city of Wuhan, cases for which the cause could not be identified. Less than 4 mo later, on April 26, 2020, Tyson Foods ran a full-page advertisement in the Sunday versions of both the New York Times and Washington Post in which Tyson Foods Chair of the Board John H. Tyson warned that “the food supply chain is breaking” (Mansoor, 2020). COVID-19 progressed from a relative handful of anomalous respiratory cases in a provincial capital in China to threatening to collapse the US food supply chain, one of the most sophisticated in the world, in a span of not much over 100 d. This was truly an unprecedented world-historical event. The question now is, what did we learn from this event that might help us to reduce the vulnerability of our food production, processing, and distribution systems to the disruptive effects of futures shocks? Addressing these questions is the subject of this paper.

The purpose of this article is to synthesize several disparate threads within the literature that help to contextualize the COVID-19 pandemic and thus clarify both its immediate effects as well as its longer-term implications for agricultural markets. Although not primarily a work of original research, this article will demonstrate that a considerable body of work in a multitude of disciplines has already supplied many of the concepts and tools required to address many of the issues raised by COVID-19. Still, the pandemic and its ongoing disruptions present a significant challenge to participants at all levels of agricultural and food product markets. The unprecedented steps taken to address this challenge will themselves have important implications that merit thoughtful consideration.
COVID-19 MARKET EFFECTS

The COVID-19 pandemic fits neatly into a class of disruptive events that Ivanov and Das (2020, p. 91) classify as “low-frequency-high-impact” or LFHI events. While firms have invested considerable time and money into hardening their supply chains against such events, the COVID-19 pandemic proved to be exceptionally disruptive nonetheless.

Several aspects of the COVID-19 pandemic served to make it a particularly difficult event to manage. First, it was not a discrete event, occurring at a point in time (like a blizzard or an earthquake) or over a relatively short interval (like a drought). The essentially open-ended character of the pandemic, coupled with the inherent uncertainty about its ultimate severity, heightened the perception of risk and made appropriate real-time management of the risk quite difficult. As Ivanov and Das (2020, p. 91) observe,

In contrast to geographically centered, singular occurrence natural/industrial disasters, a pandemic is not limited to a particular region or confined to a particular time period. Different components of a [supply chain] are affected sequentially or concurrently—manufacturing, distribution centers (DCs), logistics, and markets can become paralyzed within overlapping time windows.

The pandemic was a difficult management challenge not only for producers—farmers, ranchers, processors, and others involved in food supply chains—but also for households. This aspect of the pandemic was quite unusual. Consider how stores in many parts of the country get emptied of bread and milk on expectations of a few inches of snow that everyone knows will be gone in no more than 2 or 3 d. How much bread and milk do you lay by for a pandemic? How much meat? How much toilet paper? The answer for many consumers, to misappropriate a well-known observation by J. D. Rockefeller, seems to have been “just a little bit more.”

The effects of pandemic-related uncertainty on both producers and consumers points to the second aspect of the pandemic that contributed to its complexity. Market shocks typically affect only (or at least primarily) one side of the market: a fire in a packing plant curtails supply, a food safety scare reduces demand. The COVID pandemic was a major shock to both supply and demand simultaneously. Not only that, but the dynamics of the shocks were quite complex. Initially, consumer demand for food products surged, as stockpiling behavior contributed to a surge in demand for staple items, even as the economy remained generally open. In the protein sector, processors responded to this surge by increasing production. As economic activity slowed down—due both to changes in consumer behavior in the pandemic (risk avoidance) as well as to active policy interventions (full or partial shutdowns affecting most of the country)—demand was negatively affected both by the near-total loss of food service outlets and by a consumer shift to precautionary saving. On the supply side, the severe, negative shock came in the form of plant slowdowns and shutdowns as COVID kept workers at home—whether due to illness, quarantine for exposure, or risk avoidance. In addition, COVID-induced restrictions on processing throughput due to social distancing measures and additional health, safety, and sanitation measures further constricted supply.

Finally, with all that was already going on in processing plants, many firms were also forced to coordinate intra-company shifts from food service production to grocery retail. This was a massively disruptive undertaking for the processing sector. In many cases, entire processing facilities were dedicated specifically to the food service supply chain. (This seems to be particularly common in the poultry sector, where not only packaging and labeling but also key product specifications—for example, the size of a particular cut—can differ significantly between food service and retail channels.) This rapid food-service–to–retail reallocation therefore involved a host of major supply chain adjustments related to product specifications, packaging, labeling, and logistics that were not trivial to execute. In many cases, product specifications tied all the way back to farm-level production practices and so entailed not only plant- or firm-level adjustments but entire supply chain modifications.

The complexity of the pandemic shocks, particularly in the protein sector, is evidenced further by the fact that even within the same industry, different specific products were affected very differently as pandemic-related effects unfolded: panic buying, loss of food service outlets, and, finally, significant processing plant disruptions. Peel (2021) provided a good summary of this particular dynamic for the beef industry, noting that the loss of food service business affected beef tenderloin much more negatively than it affected cuts used for roasts. Subsequently, as processing plant disruptions came to the fore, prices on all product classes rose sharply as supplies were curtailed by processing plant disruptions, with trim product prices far eclipsing all previous records.

The causes and effects of the massive supply chain disruptions are explainable in hindsight, though they were certainly evolving daily during spring of 2020. Government response and human responses to limit the spread of COVID-19 led to major shifts in where and when food was available and needed. Stay-at-home orders, closures of restaurant dining rooms, and risk avoidance behavior by consumers led to a sharp decline in food consumed away from home. During April 2020, approximately two-thirds of US consumer spending on food was at food-at-home retailers (Sinclair and Zeballos, 2021). This was the highest level on record. On an annual basis, food expenditures at eating-out businesses declined by 18% in 2020 as compared with 2019 while food-at-home purchases increased by 8.5%.
The major supply-and-demand disruptions hit the animal protein supply chains at the packing and further processing stage of production. The swift and sharp shift in how and where consumers wanted protein caused a spike in demand for protein packaged for retail consumption and a need to convert protein packaged for food service. On the supply side, the packing sector relies on a relatively large labor force that often works in close proximity to one another. Measures to ensure social distancing were difficult to implement quickly. Absenteeism soared for several reasons such as risk avoidance, lack of childcare when schools closed, or because workers were sick or quarantined. Lack of available workers led directly to plant closures or slowdowns for periods of time (Polansek and Sullivan, 2020).

The cheese market provides an interesting case study in the evolution of COVID-19 market effects. It is a market that clearly includes large food service and grocery retail demand components, with plants and firms that specialize in one sector or the other along, with some plants or firms serving both sectors. The dynamic character of COVID-19 market shocks is thus evident in the experience of that market. That experience is well documented in the weekly Dairy Market News summary reports published by the USDA Agricultural Marketing Service. These reports are archived online at https://www.ams.usda.gov/market-news/dairy-market-news-weekly-printed-reports.

The first mention of a coronavirus in the “Cheese Highlights” section of the weekly Dairy Market News report appeared in the report for the final week of February—surprisingly late, in hindsight:

Cheesemakers are running near to or at capacity… Cheese market tones, like most of dairy and other ag commodity markets in the midst of the coronavirus concern, are shaky (USDA, AMS, 2021a).

Two weeks later, the implications of COVID-19 were coming into sharper focus, though the full ramifications of the pandemic event were obviously not fully apprehended by market participants:

There are obvious concerns about cheese orders regarding the coronavirus outbreak. Expectations are, and some evidence has already shown, that food service orders could take a bearish hit. Retail orders, however, could pick up as more people stock up on food supplies at their local groceries. Cheese production is busy… Cheese market tones are positive, but with caution (USDA, AMS, 2021b).

By the following week, though, the other shoe had definitely dropped:

Throughout the country, retail orders have climbed…food service orders have nearly dissolved. The coronavirus epidemic has cleared grocery store shelves of necessities… That positive push, though, cannot be said for cheese producers who are significantly affected by school closures… Cheese production is also mixed. There are plants running 7-days a week. However, there are some that are closed for scheduled maintenance (USDA, AMS, 2021c).

In short, the cheese production sector progressed from running at full capacity to having a significant segment of the sector running over normal capacity and a significant segment being completely shut down in a span of 3 wk. Note that this disruption was due almost entirely to the effects of the differential demand shocks on food service versus grocery retail demand. It was not (at that point) related to worker absenteeism or COVID mitigation measures in plants. Note further that this level of disruption occurred in a market for product that is relatively storable in comparison to fresh food products (e.g., fresh meats, fruits, vegetables). By comparison, the meat processing sector faced, arguably, a significantly more difficult challenge than the cheese sector—particularly once COVID-19 started directly affecting workers in significant numbers, hence Mr. Tyson’s rather dire late-April warning about a breaking food supply chain.

At the time of Mr. Tyson’s warning, the most significant problems in the food supply chain were occurring in the beef and pork processing sectors. These problems are traced out in fairly stark terms in the weekly meat production data reported by the Agricultural Marketing Service. Weekly beef and pork production are summarized in Figures 1a and 1b, comparing 2020 with the previous 2 yr. Both data series show (1) the early surge in production as processors increased production to meet stockpiling demand (and, likely, in anticipation of developing operational challenges in plants), (2) the sharp drop in production as COVID-related effects directly impinged on plant operations and shutdowns affected demand for retail product, and (3) the relatively quick rebound as adjustments in policy (essential worker designation for plant workers) and plant-level adaptations permitted a resumption of near-normal operations. For some perspective on these charts, between the week ending March 28 and the week ending May 2, weekly federally inspected beef production dropped by 37% and pork production dropped by 44%; these are clearly dramatic effects being manifest in a very short time frame.

**ECONOMIC ISSUES RELATED TO SUPPLY CHAIN DISRUPTIONS**

The supply chain effects of COVID-19 presented several economic challenges for the individuals and firms operating within those chains. These challenges show up clearly in the meat processing sector as a significant increase in risk and a dramatic widening of marketing margins. An exhaustive review of economic effects from COVID-19 is found in the study by Lusk et al. (2020). The goal of this
section was to review concepts related to economic risk and marketing margins during the pandemic.

**Risk**

COVID-19 is a textbook example of a black swan event: an extreme outlier that is hard to anticipate and, therefore, to manage. At the beginning of the pandemic, the risks associated with COVID were challenging for food supply chains to predict. Through experience and as more information became available, food supply chains have learned about and managed pandemic-related risks more effectively.

The types of risk that agricultural supply chains have been subject to during the pandemic can be classified as production and price risks. Production risk refers to a scenario where realized output differs from expected output. Similarly, price risk occurs when price expectations differ from actual prices. Both risks were elevated by COVID-19–induced shocks to the food supply chain. In fact, one of the biggest challenges of COVID-19 was that its disruptions to food supply chains simultaneously changed

![Graphs showing US weekly federally inspected beef and pork production (2018-2020)](image)

**Figure 1.** (a) US weekly federally inspected beef production: 2018 to 2020. Data source: USDA Agricultural Marketing Service through the Livestock Marketing Information Center. (b) US weekly federally inspected pork production: 2018 to 2020. Data source: USDA Agricultural Marketing Service through the Livestock Marketing Information Center.
production and price risks, which firms had to navigate and manage. Figures 1a and 1b suggest that meat processing firms experienced extreme production risk during the pandemic. The meat sector reflects an extreme case but many firms in the agricultural supply chain experienced similar production risks. Perhaps, the most heavily investigated production risk for food supply chains was the effect of COVID-19 on the food processing labor supply (e.g., Luckstead et al., 2020). As COVID-19 found its way into the labor supply, many food processors shut down, and many more operated at reduced capacity. Although food retailers faced similar labor challenges, they were generally able to more quickly implement the proper personal protective equipment, social distancing, and quarantine protocols. Clearly, output was lower than expected, and per unit production costs increased significantly. The combined effects of the shocks to the food processing sector permeated through supply chains and created new sources of risk for animal protein producers. Closures or slowdowns of packing plants led to a logjam of market-ready live animals with nowhere to go. Specifically, disruptions to food processing reflected a decrease in demand for farm products. The shift in processor’ demand put downward pressure on commodity prices, and in several instances, left farms searching for new buyers for their products. The value of live animals dropped sharply as there were more animals than there was processing capacity. Anecdotally, the most extreme example of this was the mass depopulation of pigs on commercial hog operations (e.g., Cema, 2020). The beef cattle production system was forced to slow and adjust to the reduced processing capacity as cattle stayed in feedlots longer and cattle backed-up throughout the supply chain (Martinez et al., 2021). Overall, animal protein producers faced extreme price shocks in a very short period of time.

Before the COVID-19 shocks to the supply chain, increased price risk was immediately realized by the reaction that commodity markets had during the early stages of the pandemic in 2020. The initial reaction of commodity futures markets was primarily a spillover effect from the significant decline in stock market value (Anderson, 2020). Commodity futures markets had a similar reaction following the March 13, 2020, announcement that the United States had declared COVID-19 a national emergency (Figure 2).

Figure 2 plots an index of Friday settlement prices for the nearby contract of select commodities on the Chicago Mercantile Exchange. The base for the indices in Figure 3 is the Friday settlement price one week before the March 13 announcement. On March 13, the decline in futures prices ranged from 14.5 to 1.7% for hog and corn futures contracts, respectively (Figure 2). At their lowest, futures prices were 42.5 to 5.8% below March 6 settlement prices for hogs and soybeans, respectively (Figure 2). Throughout much of 2020, futures and spot prices would be highly volatile and move counter-seasonal for several commodities.

COVID-19 was a new source of production and price risk for agricultural supply chains. In the short run, Centers for Disease Control and Prevention guidelines are COVID-19 risk-mitigating strategies for food processors to
protect workers and prevent further disruptions to production. In the long run, a natural question is how will food processors, and more broadly, supply chains, manage future pandemics and related sources of risk? One prediction is that production systems will likely become increasingly automated (Hobbs, 2020). Automation in food supply chains presents both economic and engineering challenges. More research will be needed to assess the role of further automation in food production systems.

Price Spreads and Marketing Margins

The aforementioned shocks to the US food system during the early stages of the pandemic resulted in large movements in farm, wholesale, and retail prices. The difference between these 3 prices for a specific product is called the price spread. The farm-to-wholesale pork price spread is the difference between finished hog and wholesale pork prices. Similarly, the farm-to-wholesale beef price spread is the difference between fed cattle and wholesale beef prices. These price spreads are also called marketing margins. More precisely, marketing margins are intended to capture any costs associated with transforming a farm product into a consumer good (Wohlgenant, 2001). Lusk et al. (2020) argue that, at best, a price spread is a rough approximation of the marketing margin. Still, price spreads and marketing margins for beef and pork received considerable attention during the early stages of the pandemic and will be the focus of this section.

Figure 3 plots USDA-Economic Research Service farm-to-wholesale price spreads for pork and beef. [See the study by Hahn (2004) for documentation on meat price spread calculations.] In May 2020, the farm-to-wholesale price spreads for beef and pork were $390/hundredweight (cwt, 45.36 kg) and $119/cwt. Lusk et al. (2020) showed that the large price spreads during the pandemic are explained more by increasing wholesale prices than decreasing livestock prices. A similar result would be found by decomposing the data in Figure 3 into the separate farm and wholesale prices. Lusk et al. (2020) also found that wholesale meat prices were more volatile than livestock prices during the January to June 2020 period.

These large beef and pork price spreads received heavy scrutiny throughout the major disruptive periods of the pandemic. However, the divergence between cattle and hog and beef and pork prices are explained by standard economic concepts. Pork and beef packers are margin operators who produce wholesale meat products (production outputs) by slaughtering and processing hogs and cattle (production inputs), respectively. Thus, packers reflect demand for hogs and cattle. Because many plants were shut down and many more were producing at reduced capacity, packers could not slaughter and process as many animals as they normally would. Such a scenario refers to an inward shift (decrease, to the left) in demand for cattle and hogs. All else equal, an inward demand shift will decrease cattle and hog prices.

At the same time, plant shutdowns and reduced processing capacity meant that packers could not produce as much wholesale product as usual. This scenario refers to a situation where packer supply of pork and beef shifts inward (decrease, to the left). Coupled with a demand spike from consumer panic buying (at least partially fueled by a rapid policy response that put significant additional cash in consumers’ hands during the panic-buying phase of the pandemic), an inward shift in packer supply will increase wholesale meat prices. Together with observations from Lusk et al. (2020), the economic concepts outlined here suggest that supply chain disruptions were absorbed by
beef and pork packers and transmitted primarily via higher meat prices rather than lower livestock prices.

**Supply Chain Resilience**

The economic disruptions triggered by the COVID-19 pandemic have stimulated a great deal of conversation, in both academic and industry circles, about supply chain resilience (see, e.g., Hobbs, 2020; Ivanov and Das, 2020; Sharma et al., 2020; Ali et al., 2021; Nandi et al., 2021). It is useful to establish clearly what that term entails.

The resilience of networks of various types has been a focus of research since well before the COVID pandemic. A rich literature on the subject thus provides a ready framework for evaluating supply chain issues in light of the challenges presented by COVID. For example, Ivanov and Das (2020) identified 4 levels of supply chain reaction to disturbances, presented here in order of increasing resistance to negative effects:

- **Stability**—ability to recover from a shock;
- **Robustness**—ability to withstand a shock while maintaining performance;
- **Resilience**—a combination of stability and resilience, this is the ability to withstand a shock and recover performance after shock; and
- **Viability**—a supply chain’s ability to survive in a changing environment over a long period of time though adaptation.

To this point, most of the discussions of food and agricultural product supply chains have focused on the shorter-run aspects of the robustness and resilience of these systems in the face of the pandemic’s effects, with the longer-run concept of viability increasingly the subject of strategic consideration (e.g., see the study by Ivanov and Dolgui, 2020), though it is not at all clear that consensus on the attributes and components of viable supply chains will be easily achieved.

Wang and Zhang (2018) explored the causes of cascading failure in complex networks—that is, a break-down in operations across a network as one or more components of the network fails. They note that in many information and technology networks, the primary source of cascading failures is overloading (think, for example, of an electrical grid). Although, applying network failure concepts specifically to supply chains, they note failure is more likely to result from shocks that lead to underloading problems. For example, the disruption of an upstream supplier may cause the failure of a downstream operation unable to secure necessary inputs. Similarly, the disruption of a downstream firm may eliminate a key market for an upstream supplier, resulting in a cessation of operations for the supplier. Their work quite accurately anticipates the food supply chain disruptions that occurred during the worst of the pandemic, particularly in the protein sector. Unfortunately, they produce no easy solutions for improving the resilience of a supply chain, citing only improving firm core competence and spare capacity across different nodes of the network as the primary means of avoiding cascading network failures.

Network reliability research points toward the value of networks that are resistant to disruption: robust or resilient, in the terminology of Ivanov and Das. Gertsbakh et al. (2018) explored network reliability, investigating the effects on network robustness of the distribution of network components that are resistant to disruption (i.e., “strong” components). This work shows how such components can reduce the likelihood of failure, but it is not able to specify what, specifically, makes a network component resistant to failure. That, clearly, is quite situation specific. Identifying key characteristics of food supply chain operations that were most resistant to disruption during the pandemic may be possible, but it remains to be seen whether specific recommendations for facilities, operations management, and supply chain coordination strategies will be forthcoming. It is entirely possible that the keys to relative success during the pandemic devolve to something like Wang and Zhang’s (2018) competence in core management functions and spare capacity—good to know but somewhat difficult to translate into specific, actionable recommendations.

Norwood and Peel (2021) offer some specific recommendations on improving supply chain resilience, but these relate not to specific operational strategies but rather to risk assessment and preparation through better supply chain mapping and contingency identification and planning. One benefit of their approach is that it encourages a thorough assessment of where supply chain vulnerabilities are and precisely what is giving rise to those vulnerabilities, with an eye to mitigating them before a disruptive event occurs—for example, identifying and establishing a relationship with a back-up supplier of a key component in the event that the primary supplier fails.

From a strategic point of view, it is worth considering what factors contributed to the perceived lack of robustness or resilience observed at the height of the pandemic. In a general sense, the major features of supply chains—particularly in the protein sector—that made pandemic-related interruptions so disruptive were their scale and their level of specialization. Note that these features are related: effective specialization is likely only feasible at some minimum scale or, viewed in the other direction, specialization (e.g., focus on only 1 or 2 packaging specifications) facilitates efficient operation at larger scale. Here, it is essential to recognize that specialization and scale are not incidental attributes of the modern supply chain; they are, rather, essential. Supply chains have been engineered quite intentionally to be both highly specialized and sufficiently large to capture any available economies of size. It is no mystery why this has occurred. Specialization and the realization of economies of size create efficiencies that reduce per unit production costs. The economic incentives for this evolution of supply chains has been quite strong. This has been conspicuously true in the protein sector. The presence, particularly, of significant
economies of size in the operation of meatpacking plants has been well documented and rigorously quantified.

MacDonald and Ollinger (2005) estimated that per-head processing costs in the beef packing sector were brought down by over 35% from the consolidation and consequent increase in scale of operations that occurred in the 1980s and 1990s. Similarly, Morrison Paul (2001) evaluated cost of production in beef processing using plant-level data. She found that each 1% increase in output resulted in a 0.95% increase in total costs—that is, a 5% reduction in cost on each marginal unit of output.

The operational advantages accruing to larger plants extend beyond simply lower costs due to efficiency. They also enjoy significant advantages in marketing. Such firms can more easily access national and even international markets, matching specific end products to the highest-value market for those products. This advantage becomes particularly apparent on specialty products. For example, a large processing plant is able to capture value from hide and a wide variety of offal products. Small plants often have to pay for disposal of these by-products.

Realistically, improving supply chain resilience and robustness in the protein sector will primarily have to take place within the current model of highly specialized, large-scale operations. Moving away from specialization and scale would entail a cost penalty that would, under normal operating conditions, disadvantage any firm or industry that does so. In the highly competitive global protein market, such disadvantage would almost certainly prove to be quickly fatal. In short, despite the fragilities that come with specialization and scale in an event like the recent pandemic, the day-to-day cost advantages of these supply chain attributes are undeniable. Any changes to the current system will have to recognize and respect the significance of that fact.

MITIGATING PANDEMIC EFFECTS ON FOOD SUPPLY CHAINS

In these relatively early days of pandemic postmortem, strategies geared toward altering the current commercial landscape in the food and ag sector seem to be featured more prominently than strategies geared toward hardening the current system against future shocks. Thilmany et al. (2020, p. 88) explored the performance of local and regional food supply chains during the pandemic, noting that such systems were able to respond in innovate ways to the pandemic because they are “relatively nimble and proximately connected to their supply chain partners” in comparison with the broader commercial food system. This perspective has led to considerable interest in intentionally expanding the role of local and regional food systems within the overall market. For example, early in the pandemic, Bakalis et al. (2020, p. 170) plainly stated that “increasing resilience will require enriching the current food system with shorter supply chains.” Kolodinsky et al. (2020) echoed this sentiment in discussing ways to capitalize on the interest in local food systems arising from the pandemic. Similarly, Lioutas and Charatsari (2021) identified “community marketing schemes” as a key element of a 3-pronged approach to mitigating the agriculture sector effects of future disasters. In discussing 1 of the other 2 prongs of their approach—resilience-promoting policies—they also noted the need to promote a diversity of agricultural production systems, which clearly ties in to the promotion of local food systems as well.

Certainly, the experience of the pandemic highlighted the vulnerabilities of having a food supply chain in which capacity is concentrated in a handful of large firms. The experience of the meat sector is particularly instructive here. Beef and pork production were significantly more negatively affected by plant disruptions than was chicken production because beef and pork processing are considerably more concentrated than chicken processing. Data for 2019 from the USDA, Agricultural Marketing Service, Packers and Stockyards Division (2020; most recent available) reported the 4-firm concentration ratio for steers and heifers, hogs, and chicken as 85, 70, and 54%, respectively. In general, cattle and hog processing takes place in fewer, relatively larger plants. The closure of a single beef or pork plant thus has a bigger effect on those markets than the closure of a single chicken plant.

The geographical distribution of processing also proved to be important as the severe pandemic effects on labor forces occurred in different areas at different times. The smaller and more dispersed nature of poultry processors contributed to the lesser effects as compared with beef and pork. Circumstantially at least, less concentration—smaller individual operations, broader geographic dispersion, shorter supply chains, closer local and regional connections—could provide some features of a more resilient food system.

As discussed in the previous section, a food system composed of smaller, less specialized operations would entail considerably higher costs than our current system. Proponents of this change might contest this point, arguing that the demonstrated fragility of the current system in times of stress is a real and tangible cost that must be taken into account. This is a fair point. Conceptually, the choice comes down to a system that operates at extremely low per-unit cost most of the time while being vulnerable to severe disruption (and thus high costs) in extreme events versus one that operates at relatively high per-unit cost most of the time while being potentially less vulnerable to widespread disruption. More empirical work is to define the contours of this trade-off more clearly.

Regardless of the precise accounting of the trade-off between efficiency and resilience or robustness, a wholesale overhaul of food supply chains in this country is not likely any time soon. What is likely is that the pandemic-induced interest in local food systems will lead to a surge in investment—both public and private—in such systems. Anecdotal evidence suggests this is occurring. For example, the Arkansas Department of Agriculture allocated $5
millions in funding from the Coronavirus Aid Relief and Economic Security (CARES) Act to a grant program to expand small-scale meat processing in the state (NASDA, 2020). The state of Kansas used CARES Act funds for a similar program, the Securing Local Food Systems grant, to support small-scale meat processing facilities, food processors, food banks, and direct marketing efforts of local farmers. Many other states have proposed or implemented support to boost local processing capacity. Subsequent to these state-level initiatives using the initial round of coronavirus relief funding, the coronavirus relief bill passed in December 2020 included $60 million to support federal grants to local meat processors.

At the same time interest (and investment) in local food systems is growing, commercial food processing operations are also evaluating new investments. For the meat processing sector, plant labor was a key vulnerability exposed by the pandemic. The inability to field a workforce due to illness or risk avoidance contributed greatly to processing plant disruptions. The requirements of social distancing also made managing labor in the plant much more difficult. The pandemic thus heightened the incentive to pursue automation strategies to further economize on labor in processing plants (Weersink et al., 2021). From the standpoint of improving the resilience of supply chains to a severe labor force shock, few solutions would be as beneficial as increased automation in large processors. Private investment is likely to be required to achieve these advancements.

The pandemic-related developments in both small-scale and commercial food supply chains set up a somewhat perilous situation for smaller operations. Technology adoption—and specifically the size economics associated with such adoption—have long driven consolidation in the food processing sector (MacDonald and Ollinger, 2005). There is little reason to think that similar economies will not attend any pandemic-inspired wave of technology adoption in the processing sector. This implies not only increasing incentives for further consolidation but also, more significantly, further downward pressure on per-unit costs of production and, in turn, consumer food prices. Therein lies the peril for small-scale operations in the supply chain. Competition from the commercial sector may well intensify as a result of changes set in motion by the pandemic. For short supply chain, local food systems to survive, consumer interest and engagement in such systems will have to remain strong—and such interest may well be working against an increasing cost of production disadvantage. Online sales and advertising can be a tool for these systems to reach and retain customers, but will consumer support be sufficient to maintain the economic viability of these local food systems once the public money is gone and the world returns to normal? Past experience in this regard is not particularly encouraging, but maybe the pandemic really has resulted in durable changes to consumer attitudes. Time will tell, of course.

**SUMMARY AND CONCLUSIONS**

The COVID-19 pandemic in 2020 has probably been the most disruptive event of the past generation in terms of its effects on global supply chains. The US protein supply chain was among the hardest hit sectors of the economy due to the quick succession of both supply- and demand-side effects of the pandemic. Given the significance of the supply chain disruptions and the sensitivity attached to food security issues, the pandemic experience has fostered great interest in identifying ways to improve the resilience of food supply chains. Much of this interest is centered on the protein sector.

Although the goal of improving food supply chain resilience is a worthy one, there will be no easy routes to this goal. The modern commercial food supply chain is complex, technologically advanced, and consists of firms that are massive in size to capture significant economies that keep per-unit costs of operation low. The pandemic has generated great interest in not only shortening food supply chains but also in greatly reducing the scale of operation of the chain’s components. Although this might offer advantages in terms of resilience to extreme events like the coronavirus pandemic, it would do this at the expense of efficiency of operation, resulting in higher costs throughout the system—for both consumers and producers.

Commercial food supply chains may become even more efficient in the wake of the pandemic as firms invest in further automation in response to pandemic-related labor challenges. Such investment may well drive further consolidation in the processing sector due to the economies of size associated with automation. In short, the commercial food processing and retailing sector—already impressively efficient in its operations—may become even more so. This presents a real challenge to the economic viability of small-scale, local food systems. There is a real danger that interest in smaller-scale, local food systems, which is currently catalyzing a flurry of investment in such systems, will wane as the pandemic recedes in the public’s consciousness, leaving the operations in these supply chains facing an even more competitive environment than the environment that existed before the pandemic.

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