Received: 11 August 2020 | Revised: 29 September 2020 | Accepted: 16 November 2020

DOI: 10.1002/agr.21674

RESEARCH ARTICLE

Agribusiness An International Journal WILEY

# A descriptive analysis of the COVID-19 impacts on U.S. pork, turkey, and egg markets

Dermot J. Hayes | Lee L. Schulz | Chad E. Hart | Keri L. Jacobs

Department of Economics, Iowa State University, Ames, Iowa, USA

**Correspondence**
Dermot J. Hayes, Department of Economics and Finance, Iowa State University, Ames, IA, USA.
Email: dhayes@iastate.edu

**Funding information**
USDA National Institute of Food and Agriculture Competitive Grants Program, Rapid Response to Novel Coronavirus (SARS-CoV-2) Impacts Across Food and Agricultural Systems; USDA National Institute of Food and Agriculture Hatch project 1010309

**Abstract**

The novel coronavirus SARS-CoV2 (COVID-19) severely disrupted the U.S. food supply chain. In its initial aftermath, and as we contemplate a potential reignition, the food supply chain industries, researchers, and policy makers search for evidence, causes, and consequences. This article uses publicly available data on the pork and egg industries and a survey of the turkey industry as a first step to document the impact of COVID-19. Researchers can learn from the experiences in industries where disruptions evolve differently in the face of simultaneous supply- and demand-side shocks and that stem from differences in structures of the supply chains. This early evidence is used to motivate future research needs and highlight opportunities for industry investments in resiliency strategies.

**KEYWORDS**
COVID-19 pandemic, eggs, pork, supply chain disruption, turkey

**ECONLIT CITATIONS**
L11; L14; I22; L220; M21; M210

## 1 | INTRODUCTION

The novel coronavirus SARS-CoV2 (COVID-19) created unprecedented supply and demand shocks in agriculture and food production. Many supply chains designed to function efficiently were unable to respond fully to absorb the shocks, despite the impressive changes they did implement. The system-disrupting shocks of COVID-19 and the lack of sufficient supply chain flexibility resulted in market instability for many of the major U.S. agricultural food products including pork, poultry, and eggs. In the early stages of the COVID-19 pandemic in the United States, several beef and pork packing plants were forced to close or reduce operations, laying hens and hogs were euthanized,[1] food service markets were severely restricted, and retailers rationed fresh meats and eggs.

Throughout this article, we discuss the supply shock experiences and impacts in the pork, turkey, and egg markets. Coming to terms with total system impacts also requires contemplation of the near-simultaneous demand-side shocks driven primarily by abrupt changes in consumption patterns. State and local officials implemented an array of business and school shutdowns and stay-at-home orders. These policies forced significant changes in peoples' lives, especially in food consumption patterns. Over the past decade, typical American eating patterns are such that food expenditures are divided approximately equally between consumption at home (food at home [FAH]) and away from home (FAFH), with some deviations during holidays. Figure 1 shows FAFH and FAH expenditures, in constant dollars, from January 2019 through July 2020. Beginning in January 2020, not only did total dollar expenditures on food and beverages drop significantly, bottoming out in April, but also did the proportion of FAFH expenditures. FAFH is dominated by consumption at restaurants and schools and includes food and drink expenditures at workplace cafeterias, hotels, and during travel—all restricted activities at the height of COVID-19 shutdowns. At the same time, the closures forced a significant increase in at-home food consumption (FAH). A U.S. Department of Agriculture, Economic Research Service (2020) chart using data from the Food Expenditure Series notes the uniqueness of the COVID-19 experience from previous economic shocks, including the Great Recession of 2007–2009——this was a near-unprecedented substitution away from FAFH toward FAH. Even several months into the pandemic, U.S. food expenditures continued to be dominated by FAH spending and were lower in real terms than in prior years. The substitution happened quickly and persisted, and food supply chain businesses coping with supply-side shocks faced challenging demand-side pressures.

Supply chains, and the coordination along with them, have been researched extensively in agricultural economics including a number of literature summaries and discussions of issues of coordination (Barry et al., 1992; Cotterill, 2001; Crespi & Saitone, 2018; Crespi et al., 2012; Goodhue & Rauser, 2001; Hennessy, 1996; Lawrence et al., 1997; Martinez, 2002; Moschini & Meilke, 1992; Royer & Rogers, 1998; Sexton & Lavoie, 2001; Vercammen & Schmitz, 2001). While these studies provide insights into the general structure of the market, they lack discussion of how supply chain coordination is vulnerable when large, exogenous shocks remove either the physical or human assets that are necessary to efficiently allocate inputs along the chain. There has, of course, been economic research on the impact of agricultural supply chain disruptions from infectious diseases that impact a food input (e.g., Elbakidze et al., 2009; Pendell et al., 2007, 2015; Schlenker & Villas-Boas, 2009; Schroeder et al., 2015) as well as from exogenous trade disruptions (e.g., Balistreri et al., 2018), but in those cases the vertical structure of the supply chain was not impacted, only the supplies of products along it.

Whether from fire, natural disasters, or COVID-19, even basic discussions about how the food supply chain may react under stress (e.g., the general discussion of supply chain risk in Chopra & Sodhi, 2004) are absent in the published agricultural economics literature. In short, the standing research in agricultural economics thus far assumes that efficiencies along the supply chain can be taken as the dominant objective. The novel coronavirus has laid bare that the system is inefficient in the face of a large pandemic that impacts the production methods themselves as opposed to the supply of raw materials, in this case, commodity proteins. A recent surge in new economic insights and investigations on the impact of the pandemic is unraveling the market and supply chain consequences of the confluence of COVID-19 circumstances. McEwan et al. (2020) discuss the Canadian pork industry's risk from COVID-19 based on Canada's trade relationships and the uniqueness of labor in pork. Malone et al. (2020) explore the market price impacts of COVID-19 disruptions in the egg industry and the Food and Drug Administration's (FDA's) temporary adjustments to production specifications. *Choices*, a publication by the Agricultural and Applied Economics Association, released articles on the theme, "COVID-19 and the Agricultural Industry: Labor, Supply Chains, and Consumer Behavior." The theme

[1]There is no estimate on the number of animals removed before slaughter because that number is not required to be reported. For more information on what is included in U.S. Department of Agriculture National Agricultural Statistics Service *Hogs and Pigs* report estimates, see https://www.nass.usda.gov/Education_and_Outreach/Understanding_Statistics/Hogs-and-Pigs-Inclusions.pdf.

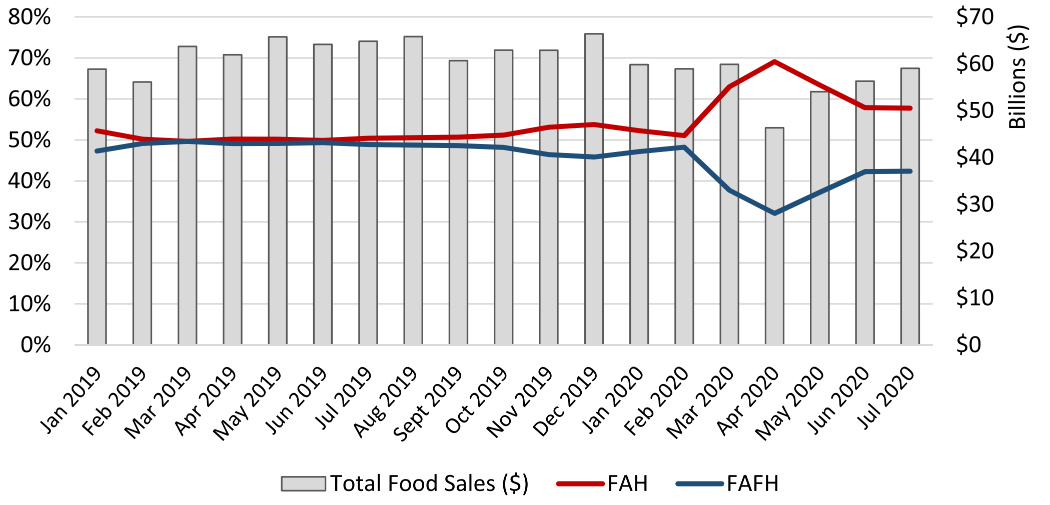


**FIGURE 1** FAH versus FAFH monthly sales. Data source: calculated by USDA, Economic Research Service from various sources, July 16, 2020. *Notes:* Constant Dollars, 1988 = 100. These estimates are sales only and exclude food furnished, donated, home-produced, and served at educational institutions. The monthly sales are benchmarked to the annual sales except for the most current year. FAFH, food away from home; FAH, food at home [Color figure can be viewed at wileyonlinelibrary.com]

overview article by Peña-Lévano et al. (2020) summarizes what the new research on the COVID-19 experiences in the agricultural industry and food supply chain points to: We are in new territory in our understanding of the consequences of major shocks to supply chains, and it is imperative that we re-evaluate our understanding of food supply chain behavior in the face of a major pandemic.

The contribution of this article is to begin to address these emerging gaps in understanding by deconstructing, in the cases of pork, egg, and turkey, the large-scale supply and demand shock impacts to these food supply chains. Lusk (2020) rightly reminds us about our COVID-19 experiences: "…the economics were straightforward…" Yet, there remains the important question—one to which we hope to contribute—about whether next time the economics could be different. With this end in mind, we document the price and market experiences in these industries to date and draw attention to industry characteristics and responses that we believe hold the key for suggesting improvements to resiliency. Much like the newly published research coming out on supply chain impacts of COVID-19 (e.g., Malone et al., 2020; McEwan et al., 2020; Peña-Lévano et al., 2020 and many more), we begin by identifying the primary disruptive point in each supply chain and then lay out the domino effects that followed up- and downstream. We view this as an important first step in ultimately identifying the system-wide implications of pandemic-scale shocks, the mitigation options that exist in various supply chains, and future research needs.

## 2 | APPROACH

We explore, in turn, how each products' supply chain and market structure created a unique susceptibility to COVID-19 disruptions. The U.S. pork industry is characterized as relatively competitive, with thousands of producers, many who contract grow for companies selling into processing markets. Major disruptions in the pork industry began in March 2020 when stay-at-home-orders for nonessential employment induced changes in product demand and then was compounded in April 2020 at the processing level due to COVID-19 exposure of essential workers and large-scale quarantining of processing labor. The processing bottlenecks quickly devolved into producer-level challenges due to the stark reduction in packing plant operations. In contrast, the U.S. turkey industry is vertically integrated, with a modest number of producers who own most of the supply chain. Its major disruption from COVID-19 was a demand-side shock as consumption switched from FAFH to FAH. Between the two extremes of the highly competitive pork industry and highly integrated turkey industry is the egg industry, where some producers sell eggs into a competitive commodity market and others have branded products. As in turkey, the primary disruption in eggs occurred at the food service level. The impacts in the egg industry were at the producer level and likely a result of the fact that in this industry, specialization for end-use markets happens very early in the supply chain at the barn level.

Data availability for these three industries varies widely. For pork, we collect publicly available data on hog prices, feeder pigs, market hogs, futures contracts, carcass cutout values, and wholesale and retail prices by cut. The turkey industry is highly integrated and data are company-owned; therefore, we rely on a survey of the industry. For eggs, the price data for wholesale and retail shell and liquid eggs are publicly available. Because there is more data available in the pork industry, we are able to provide a much broader analysis than for turkey or eggs, and therefore devote a majority of the paper to the pork industry.

## 3 | THE U.S. PORK INDUSTRY

The United States had 64,871 hog operations with sales in 2017. This consisted of 55,739 independent growers, 8,557 contract growers (contractees), and 575 contractors or integrators with annual sales of 79, 101, and 55 million head, respectively, according to the 2017 Census of Agriculture (USDA-NASS, 2019). This throughput is part of a highly efficient and coordinated system in which hogs are finished and transported to processors for prescheduled slaughter "slots." In 2017, there were 8,386 operations with production contracts and slaughter totaled almost 130 million head (USDA-NASS, 2019). When market-ready hogs move out of finishing buildings, they are replaced by feeder pigs moving from sow barns or nurseries. The decisive COVID-19 challenge for the pork industry originated at the slaughter and processing level of the supply chain and caused major disruptions in both directions. The growers upstream from processors suddenly had no outlet for their finished hogs and no space freed up for growing pigs. Downstream, food distribution markets dealt with the double-whammy of existing processed inventory ready for FAFH demand and a sharp reduction in the availability of processed pork as packing plants operations dramatically declined. In what follows, we examine how COVID-19 supply and demand disruptions in early 2020 and the ensuing months affected pork processing, the upstream impacts to growers and their pricing, and the downstream impacts to food markets and pricing of common retail pork products.

### 3.1 | Slaughter and processing capacity

Efficient and effective operation of packing plants is predicated on worker availability (Tonsor & Schulz, 2020). According to a report by the Federal Reserve Bank of Kansas City, from April to June, more than 80 beef and pork packing plants reported confirmed cases of COVID-19 and at some plants, as many as 30%–70% of the workforce was affected (Cowley, 2020). High rates of illness and absenteeism among plant employees drastically limited the available workforce. Some facilities closed for days and others for more than a week. Of the plants that did not close or that reopened after a temporary closure, many experienced a slowdown in operations due to worker availability and engineered controls such as workstation alignments and modifications, plus worker physical distancing measures that slowed line speeds.[2]

[2]*Meatpoultry.com* tracked the state of packing plant closures, slowdowns, and reopening. For a detailed timeline of events see https://www.meatpoultry.com/articles/22993-covid-19-meat-plant-map.

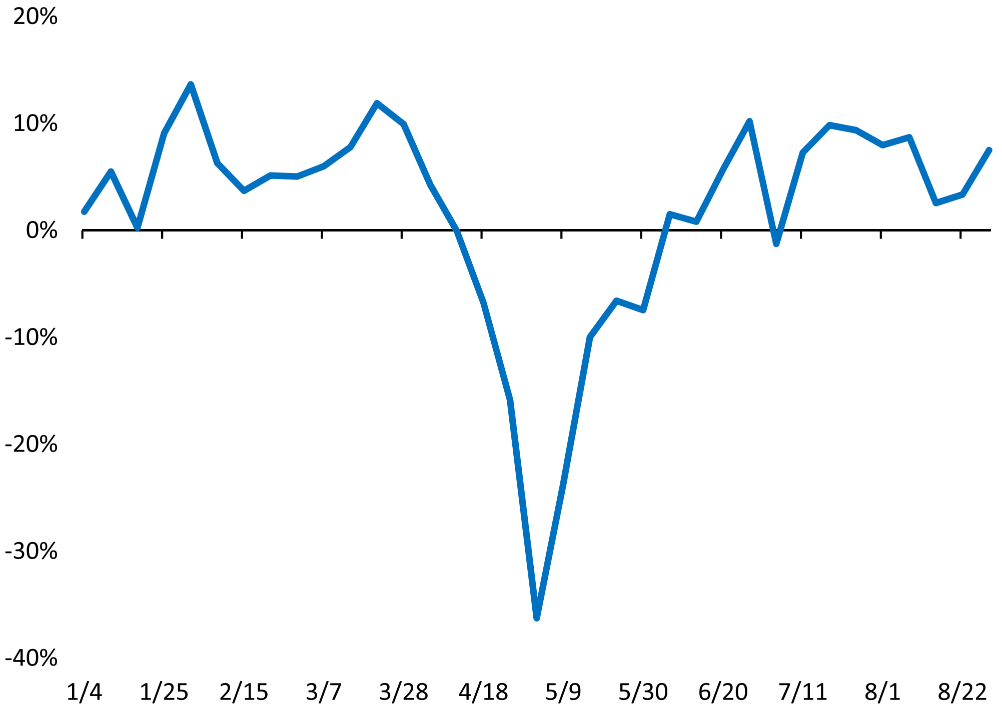


**FIGURE 2** 2020 Percentage Change in U.S. FI Barrow and Gilt Slaughter, Baseline 2019. Data Source: USDA Actual Slaughter Under Federal Inspection report (SJ_LS711), complied by the Livestock Marketing Information Center. FI, federally inspected [Color figure can be viewed at wileyonlinelibrary.com]

In the United States, like many other places in the world, COVID-19 affected regions differently. This had major implications for hog slaughter and processing capacity. Early on, COVID-19 cases were more concentrated in coastal population centers, especially in the Northeast. While New York and New Jersey have 38 of the 619 U.S. federally inspected (FI) hog packing plants they account for less than 0.1% of the slaughter volume annually (USDA-NASS, 2020). As the pandemic spread, COVID-19 cases spiked in major pork processing regions such as Iowa, Illinois, Minnesota, and Missouri. These states contain 94 FI hog plants which slaughter 56% of the annual volume (USDA-NASS, 2020). On April 28, 2020, President Donald Trump signed an executive order invoking the Defense Production Act, finding that processors of meat and poultry meet the criteria for essential infrastructure, and took all appropriate action to ensure continued operations (The White House, 2020).

To provide context on the dramatic fluctuations in pork processing volumes during the first 8 months of 2020, Figure 2 shows the year-over-year change in weekly FI barrow and gilt slaughter.[3] Year-over-year comparisons are a common metric for market analysis as the impact of seasonality is accounted for, a core factor in hog slaughter levels, and tell us how the period in question compares with “normal levels” that reflect recent (2019 in this case) slaughter capacity. This is an imperfect measure; we do not know the true U.S. barrow and gilt slaughter capacity and slaughter inventories were forecasted to be higher in 2020 than 2019, but it serves as a barometer, which can accurately capture trends and deviations from trend.

[3]Total commercial U.S. hog slaughter in 2019 was 129.913 million head, of which 129.211 million head, or 99.5%, was federally inspected (FI) with nonfederally inspected, state-inspected, or custom-exempt slaughter accounting for 702,300 head or 0.5%. Barrow and gilt slaughter is the vast majority of FI hog slaughter (97.4% in 2019), with the remaining comprising sows and boars (USDA-NASS, 2020).

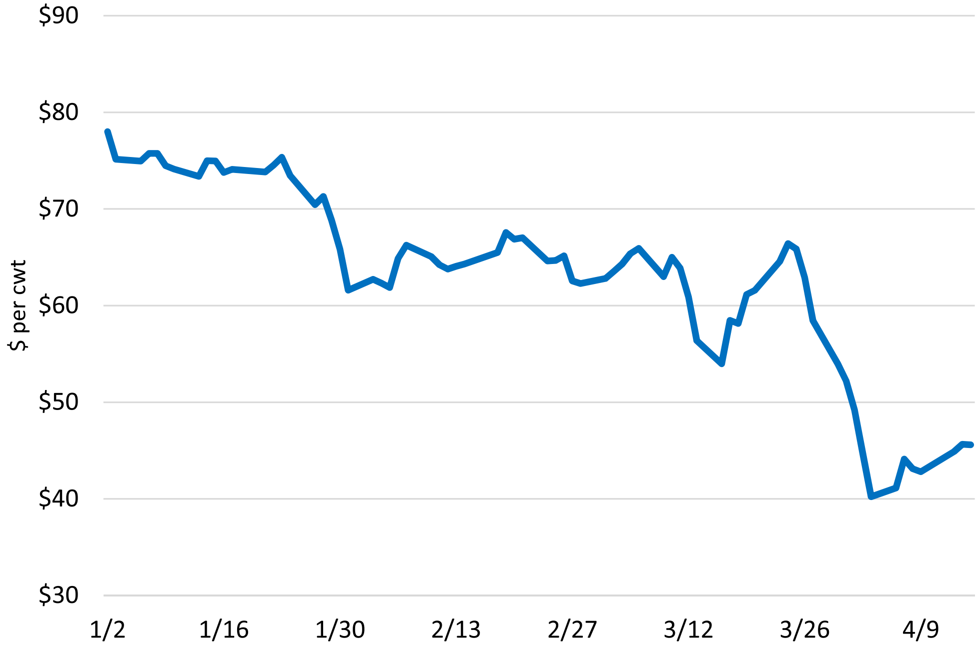


**FIGURE 3** Daily lean hog futures prices for the April 2020 contract. Data Source: Chicago Mercantile Exchange (CME) Group, complied by the Livestock Marketing Information Center. *Notes:* January 2, 2020 through April 15, 2020. [Color figure can be viewed at wileyonlinelibrary.com]

Through the first quarter of 2020, weekly barrow and gilt slaughter averaged 6.6% above year-ago levels with an average weekly slaughter of approximately 2.563 million head. Those are levels just shy of the seasonally large supplies, typical in the fourth quarter of the year. For the four reported weeks in March 2020, FI barrow and gilt slaughter topped March 2019 by 8.9% on average. The week ending March 21 saw the largest year-over-year increase at 11.9% with the following week being up 9.9%.

While the first week of April was 4.3% higher than the prior year's level at 2.497 million head slaughtered, this was 7.6% below the previous week. The week of April 11, 2.325 million head were slaughtered, slightly below the prior year and 6.9% below the previous week. The trend of lower slaughter numbers grew as plants shut down or dealt with reduced capacity in the face of COVID-19 outbreaks. For the weeks ending April 18 and 25, barrow and gilt slaughter were at just over 2.164 and 1.917 million head, respectively, representing a 6.8% and 15.9% drop each week. The largest national slaughter reduction occurred the week ending May 2, when barrow and gilt slaughter was down 36.3% compared with the same week in 2019.

In the period from week ending April 11 to week ending May 30, U.S. barrow and gilt slaughter averaged 13.3% lower than the same period in 2019, representing a decrease of over 2.424 million head. This decrease was more than a week's worth of typical slaughter at that time of year. By the first week of June 2020, slaughter volumes had recovered and average 4.6% above 2019 levels in June, 6.6% in July, and 5.5% in August based on the weekly data. Still, operational capacity continued to be constrained because of engineered controls in packing plants and labor availability. The percent of idled capacity averaged 11% in June, 6% in July, and 4% in August (Dr. S. Meyer, personal communication, Economist with Kerns and Associates, Sept. 2020).

In hindsight, the March ramp-up in slaughter shown in Figure 2 was key to creating a buffer to meet the coming FAH surge at retail stores, despite the sharp reduction in processing capacity. Hogs were pulled from finishing buildings early, providing a processed product buffer ahead of the anticipated plant closures and slowdowns in April and May. There is typically at least a 2-week lag between slaughter to the final product reaching consumers.

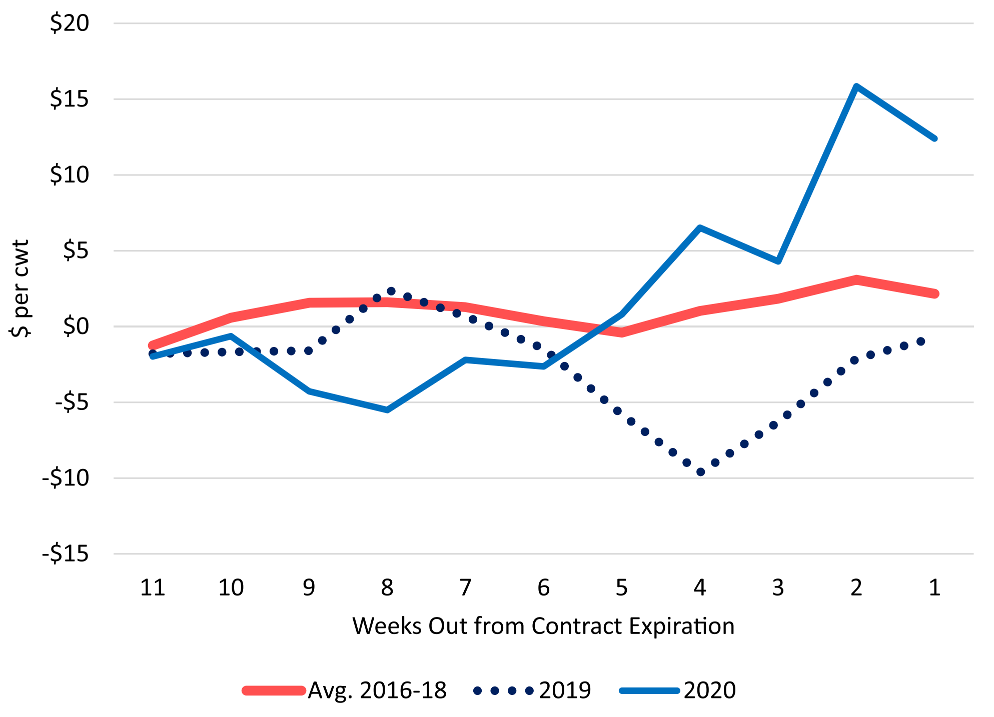


**FIGURE 4** Weekly lean hog basis, April contract. Data Source: Chicago Mercantile Exchange (CME) Group and the USDA-AMS National Daily Direct Hog Prior Day Report—Slaughtered Swine (LM_HG201), complied by the Livestock Marketing Information Center. *Notes:* Basis = Cash Price–Futures Price. The cash price is the total weighted average of all producer sold purchase types. [Color figure can be viewed at wileyonlinelibrary.com]

The industry got an early start adjusting hog diets, increasing stocking densities, sorting or topping off pens, and finding additional facilities to partially mitigate live animal supply chain disruptions. These efforts, however, were not enough to fully overcome the impacts from the massive reduction in pork processing. Finishing buildings scheduled to be emptied and restocked with feeder pigs could not be. The industry responded with attempts to tamp down the mounting processing backlog. Steps were taken to find alternative markets, including donations, and to slow animals' growth. Despite these reactions to the unprecedented situation, some euthanasia did occur.

## 3.2 | Hog futures and basis levels

The impetus of the initial buffer creation in pork processing—the ramp up of processing before COVID-19 disruptions impacted packing plants—came from the historical departure of price movements in the futures market coupled with a relative firmness in the cash market. News of the COVID-19 pandemic's migration to the United States caused futures market participants to become concerned about possible supply disruptions and demand impacts and this uncertainty drove down futures prices. Figure 3 shows the April 2020 Chicago Mercantile Exchange (CME) lean hogs futures contract pricing from January 2020 to expiration. The contract traded in the mid $70s for most of January before weakening during the last week of the month. In February and March, the contract averaged $65 and $61 per cwt, respectively. The contract last traded on April 15 at $45.60 per cwt.

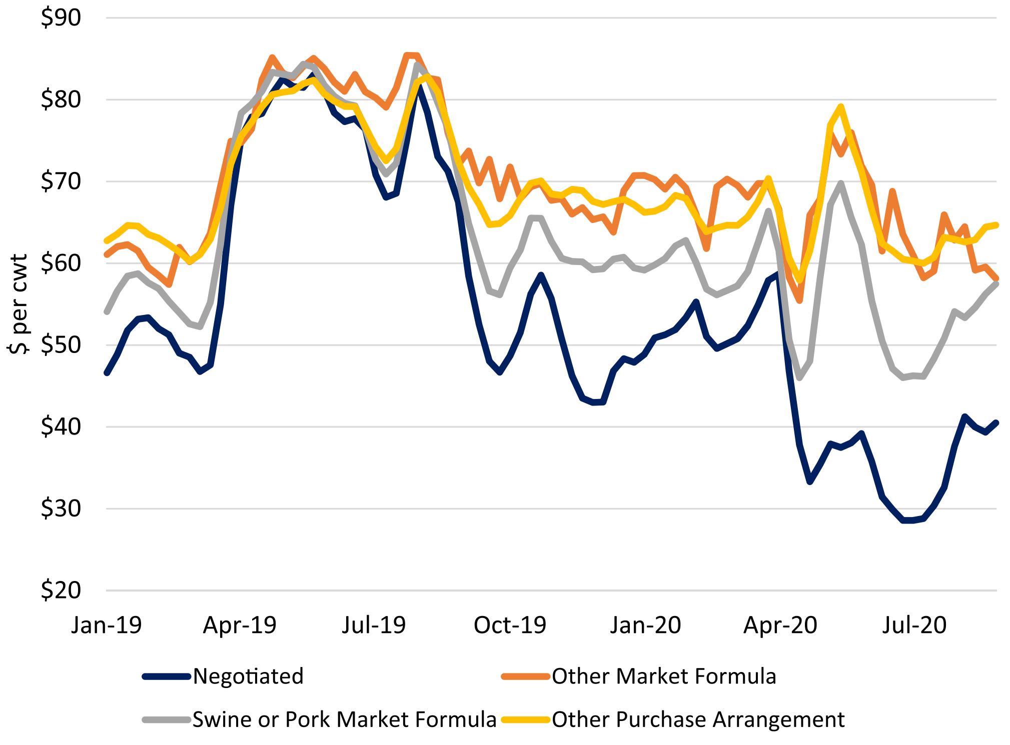


**FIGURE 5** Weekly national producer sold barrow and gilt carcass net prices. Data Source: USDA-AMS National Daily Direct Hog Prior Day Report - Slaughtered Swine report (LM_HG201), compiled by the Livestock Marketing Information Center. *Notes:* Week ending January 4, 2019 through week ending August 28, 2020. [Color figure can be viewed at wileyonlinelibrary.com]

While futures market contracts were eroding in late January through April, the cash market maintained relative firmness. Figure 4 illustrates the weighted average weekly producer sold for all purchase types hog price against the April lean hog futures contract, that is, basis, over the last several years. Note the deviations in the 2020 basis relative to 2019 and the 2016–2018 average. Early in 2020, while lean hog futures slumped, basis held within its historical norms except for a temporary drop from the second week of February to the first week of March (9–6 weeks out from contract expiration). A key to creating the processing buffer was a strong basis. As the April futures contract downturn accelerated in late-March and early-April, the cash market held strong, outpacing the futures market price dip, generating a large positive basis. Four weeks out from contract expiration basis was over $6 per cwt and jumped to over $15 per cwt 2 weeks out from expiration. A strong basis provides a signal to producers to market hogs and take the basis, especially producers who had hedged (i.e., sold futures). In contrast, a weak basis, like in 2019, is a signal to delay marketings, with the idea that the basis is likely to return to a more normal level.

Our take-away from these experiences is that a basis-driven sell signal can provide producers forewarning of potential supply chain problems, by providing incentives to market hogs ahead. Should supply chain issues reoccur, as many analysts suggest especially during seasonally larger supplies during the fourth quarter of the year, basis levels may serve as the first signal of upcoming problems.

The processing capacity issues created significant negative impacts on prices producers received for hogs (Figure 5). We present price series for producer sold barrows and gilts including data for negotiated, other market formula, swine or pork market formula, and other purchase arrangements from the National Daily Direct Hog Prior Day Report—Slaughtered Swine report (LM_HG201) compiled and converted to a weekly series by the Livestock

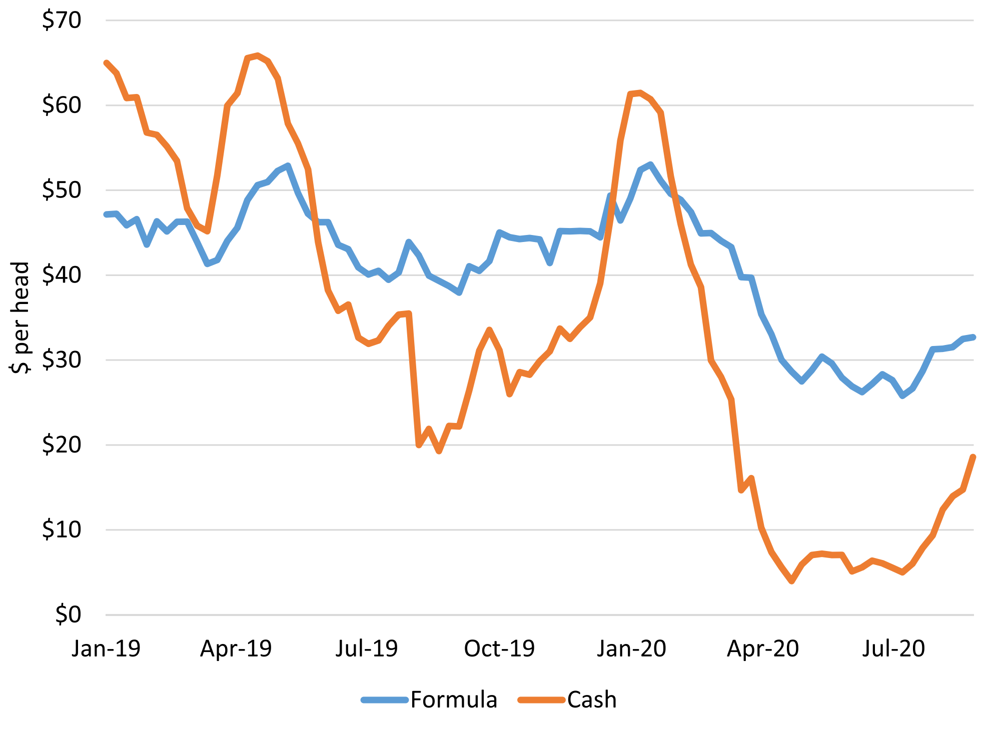


**FIGURE 6** Weekly national early-weaned pig prices. Data Source: USDA-AMS National Daily Direct Delivered Feeder Pig report (NW_LS255), compiled by the Livestock Marketing Information Center. *Notes:* Week ending January 4, 2019 through the week ending August 28, 2020. Early weaned pigs are under 21 days old and weight is for a 10–12 pound basis [Color figure can be viewed at wileyonlinelibrary.com]

Marketing Information Center (LMIC).[4] For context on the volume of each sale type, in 2019, negotiated sales represented 3% of the producer sold head count while other market formula, swine or pork market formula, and other purchase arrangement sales accounted for 19%, 44%, and 34%, respectively.

All four prices fell consistently throughout the crisis, with the negotiated price most impacted. Weakness in February and March was demand-related, one example being declines in food service activity. In April, the reduction in processing capacity drove prices down with negotiated prices falling by 43% from the week ending April 3 to the week ending April 24. The other market formula, swine or pork market formula, and other purchase arrangement prices greatly increased in mid-May as meat became scarce due to the reduction in processing capacity, while negotiated prices remained low. This pricing pattern shows that hogs sold via negotiated sales represent the marginal or residual supplies in the market; they are the first hogs to be dropped from processing and the last hogs to be brought back in once processing resumes. The backup of market-ready hogs and associated

[4]USDA's Agricultural Marketing Service, Livestock, Poultry, and Grain Market News office provides definitions with details regarding the various purchase types (USDA-AMS, 2017). The negotiated price is a cash or spot market purchase price by a packer of hogs from a producer under which the base price for the hogs is determined or known by seller–buyer interactions and agreements regardless of the method of price discovery used on a delivery day. Delivery must occur within 14 days. The other market formula price is a purchase price of hogs by a packer in which the pricing mechanism is a formula price based on one or more futures or option contracts. For example, one potential formula price is an agreement to use a $2.00 basis off the nearby Chicago Mercantile Exchange (CME) futures contract. The swine or pork market formula price represents a purchase price of hogs by a packer in which the pricing mechanism is a formula price based on a market for hogs, CME Lean Hog Index, pork, or pork product. An example of this type of pricing arrangement is 90% of the pork carcass cutout price. The other purchase arrangement price is a catch-all for price discovery methods that do not fit into the other three categories and includes hogs that receive premiums for noncarcass characteristics such as genetic line, rearing method, and raised without ractopamine and/or antibiotics.

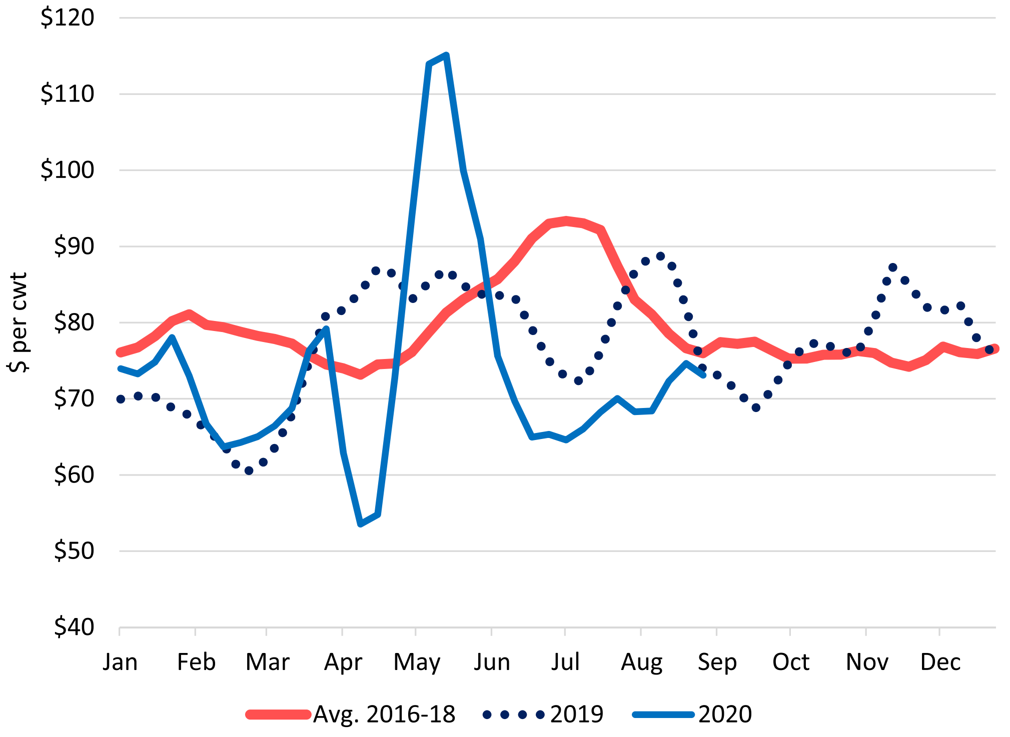


**FIGURE 7** Weekly national negotiated pork carcass cutout value. Data Source: USDA-AMS National Daily Pork Report FOB Plant—Negotiated Sales— Afternoon report (LM_PK602), complied by the Livestock Marketing Information Center [Color figure can be viewed at wileyonlinelibrary.com]

scarcity of slaughter capacity relative to available supplies kept negotiated prices at low levels. In the fourth quarter of the year, as was the case in 2019, the spread between negotiated and formula prices increased but the magnitude and the longevity of the divergence that began in May 2020 were the largest and longest in the history of the data back to August 2001.

Figure 6 shows the upstream impacts of the crisis and backlog on feeder pig prices. Prices are quoted on a per head basis delivered to the buyer's farm and include freight and fees and are provided by the USDA-AMS National Direct Delivered Feeder Pig report (NW_LS255), compiled by LMIC. The cash price started to fall in January, more than seasonal tendencies would suggest, as the farms who would normally have fed these pigs became concerned about the worldwide impact of the virus. Factors such as expected market hog prices, feed prices, pig supply, availability of nursery and finishing space, and interest rates typically cause the value of weaned pigs to vary greatly through time. The cash price fell to about $6 per head on average (the lower end of the price range was $1.00 per head for several sales) in April and held there until late July. Prices remained low, in part, because expected market hog prices, as suggested by the lean hog futures market during that time, were trading at levels well below production cost. As with the finished hog market, prices derived or determined from the futures market or a formula based on the cost of production provided more stability than that observed in cash prices.

## 3.3 | Pricing of wholesale and retail pork

Prices in the pork product markets downstream from processing showed signs of stress, first from the surge in FAH expenditures and demand in retail markets and then additionally from the reduction in processing capacity. Figure 7

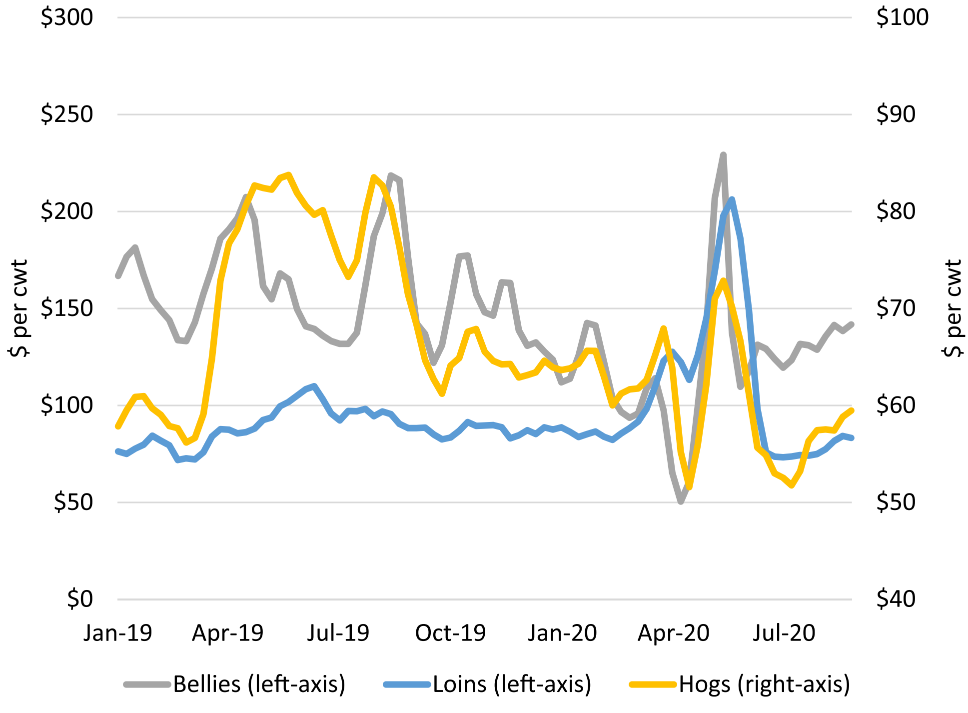


**FIGURE 8** Weekly national wholesale belly and loin prices and producer sold barrow and gilt carcass net prices. Data Source: USDA-AMS National Weekly Pork Report FOB Plant–Negotiated Sales (LM_PK610), Formula Sales (LM_PK620), and Forward Sales (LM_PK630) reports and USDA-AMS National Daily Direct Hog Prior Day Report—Slaughtered Swine report (LM_HG201), complied by the Livestock Marketing Information Center. *Notes:* Week ending January 4, 2019 through the week ending August 28, 2020. Belly and loin prices are FOB Plant, Derind Belly 13-17# and 1/4 Trimmed Loin VAC, respectively. Hog prices are the total weighted average of all producer sold purchase types [Color figure can be viewed at wileyonlinelibrary.com]

shows how the crisis impacted the value of the pork carcass cutout as derived by USDA-AMS in the National Daily Pork Report FOB Plant—Negotiated Sales—Afternoon report (LM_PK602) compiled by LMIC into a weekly series. This value is calculated by synthetically rebuilding the carcass using the wholesale value of each primal cut. Cutout values increased in late-February and March consistent with the surge in retail demand and “stocking-up” behavior and then fell in late March and early April as food service demand fell. They then surged in late April and early May as packing plants idled capacity and pork became scarce. Values fell again as packing plants resumed operations.

Figure 8 compares the wholesale prices of pork bellies and pork loins against the weighted average hog price received by pork producers (LM_HG201 report) and shows that even within a single species, consumption pattern changes lead to diverging prices of individual pork products. Belly prices fell in late March and early April as food service demand fell off and then recovered sharply in mid-May after the reduction in packing plant throughput lead to pork scarcity. In contrast to bellies, loin prices increased relative to historical levels in April as consumers began to stockpile meat and they increased again as pork became scarce. Belly prices picked up again in June and July as food service reopened. The difference in belly and loin prices reflects consumers’ preferences for pork products——more bacon is consumed away from home, but loins are typically consumed in the FAH market. Prices of bellies and loins tracked the weighted average hog price received by producers, in part, because some producers receive a formula price that is related to the carcass value.

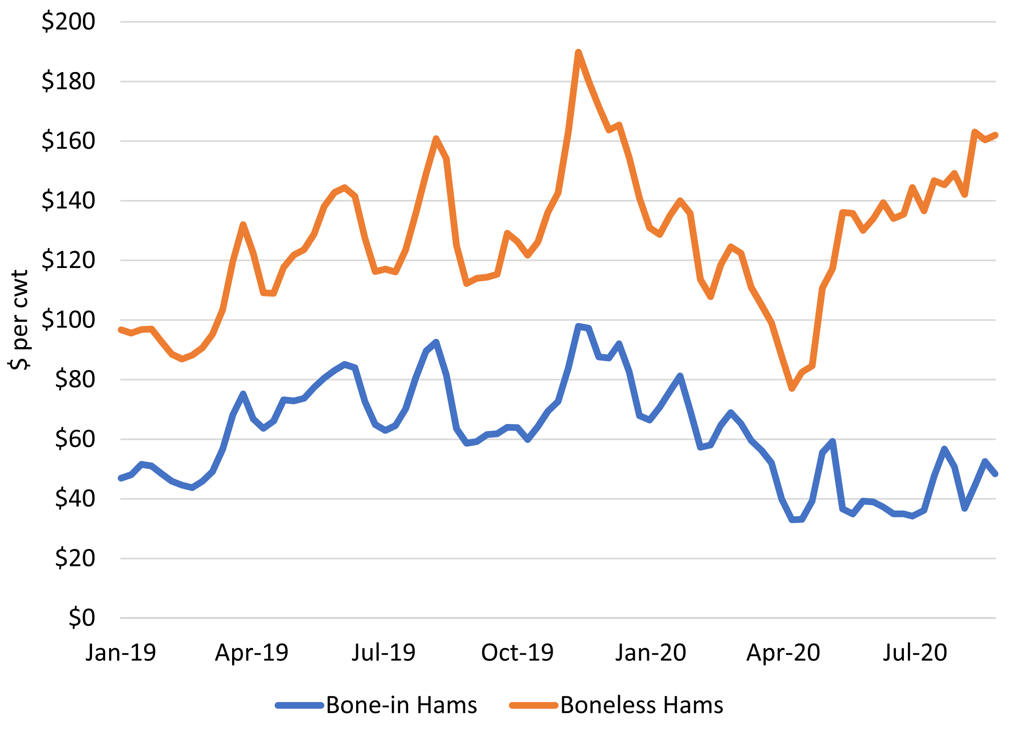


**FIGURE 9** Weekly national wholesale bone-in and boneless ham prices. Data Source: USDA-AMS National Weekly Pork Report FOB Plant—Negotiated Sales (LM_PK610), Formula Sales (LM_PK620), and Forward Sales (LM_PK630) reports. *Notes*: Week ending January 4, 2019 through the week ending August 28, 2020. Bone-in and boneless ham prices are FOB Plant, 23-27# Trimmed Selected Ham and Insides, Outsides, Knuckles, and Lite Butt, respectively [Color figure can be viewed at wileyonlinelibrary.com]

Other pork product pricing showed similar patterns that can be traced to consumption demand changes and processing capacity issues. Prices for bone-in and boneless hams (Figure 9) diverged from a normal 4:7 ratio to a 1:3 ratio because the specialized labor required to debone hams became scarce and exports of bone-in hams to Mexico fell as the dollar strengthened against the peso.[5]

The weekly retail prices of pork chops, boneless hams, and sliced bacon are shown in Figure 10. These prices are from the USDA-AMS National Weekly Retail Activity Report for pork that provides a summary of weighted average prices for pork cuts being promoted or featured in supermarkets. USDA-AMS gathers information from publicly available sources including store circulars, newspaper ads, and retailer websites. These advertised prices provide no indication on sales volume.

At times during COVID-19, feature activity was light with several retailers suspending ads or offering reduced versions. Interestingly, these retail prices were relatively stable despite the chaos in packing plants and hog markets. It appears that retailers took advantage of the reduction in primal prices and then absorbed the increase in wholesale prices when pork was scarce. In this latter case, we see retailers rationing available supplies rather than using prices to ration demand. Schroeder (1988) provides an explanation for this behavior. Retail grocers plan sales many weeks in advance——to schedule advertising and ensure logistics of product supply. Changing retail prices is costly in terms of time and materials as well as customer

[5]Exports of pork to Mexico dropped from 67.5 million pounds in March 2020 to 40.3 million pounds in May 2020. Source: United States Consumption Domestic Exports to Mexico, Monthly Series, February–July 2020, Trade Data Monitor. https://www.tdmlogin.com/tdm/default.asp.

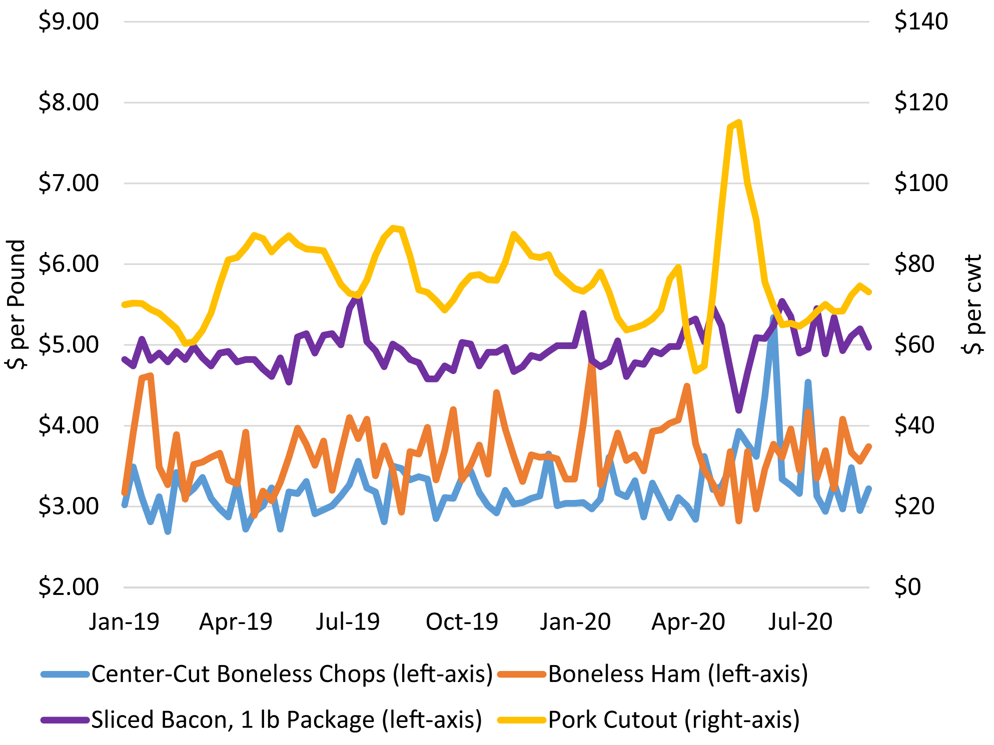


**FIGURE 10** Weekly national featured retail pork prices and pork carcass cutout values. Data Source: USDA-AMS National Weekly Retail Activity Report for pork and the USDA-AMS National Daily Pork Report FOB Plant - Negotiated Sales - Afternoon report (LM_PK602), compiled by the Livestock Marketing Information Center. *Notes*: Week ending January 3, 2019 for retail and January 4, 2019 for wholesale through the week ending August 27, 2020 and August 28, 2020, respectively [Color figure can be viewed at wileyonlinelibrary.com]

goodwill. Altogether, this provides further evidence that retail prices can be somewhat rigid relative to changes in wholesale prices even during major disruptions.

The impact of the COVID-19 crisis and the supply and demand shocks that ensued were greatest for producers of feeder pigs sold on the spot (cash) market and for producers who sold finished hogs on a negotiated basis. Many argue that these markets, especially for finished hogs, are residual markets (Franken & Parcell, 2012; McBride & Key, 2003; Schroeder & Ward, 2000). Value determination became especially difficult and in some areas of the country, and for some producers, no supply and demand interaction existed.

Meyer (2020) provides the economics of the situation. The demand for hogs is derived from the demand for pork. The supply of pork is derived from the supply of hogs. This includes not only the quantity of hogs but also the combinations of the quantities that producers will supply at alternative prices. The marginal cost of slaughter and processing services is what transforms wholesale pork demand to hog demand and hog supply to wholesale pork supply. Marginal cost is simply measured as the change in total cost for a one-unit change in quantity. If slaughter and processing services are up against a fixed and definitive constraint, as was especially the case during April and May 2020, the change in quantity can only be near zero. Because the denominator of the marginal cost ratio is near zero, the marginal cost itself is near infinite and the demand for hogs is near perfectly inelastic at the level of packing plant operational capacity. The supply of hogs is near perfectly inelastic at some higher quantity. This situation leads to an indeterminate price which could be anything from zero up to what packers decide to pay (Meyer, 2016, 2020).

An analogous case can be made for the live animal component of the industry. When hogs are backed up on the farm, producers do not need as many hogs. That is, there is an excess supply of hogs given the available finishing capacity. Growers and finishers are not able to take any more pigs and farrowing units and nurseries are not able to ship any fewer. Again, the result is an indeterminate price.

The price impact was smallest at the retail level. The surge in hog slaughter before the packing plant closures was fortuitous and appears to have been driven by a drop in futures prices that was not fully reflected in cash prices for hogs. This signal may occur again if a packing plant capacity issue is expected by traders on the CME futures market.

The packing plant capacity issue was severe because the industry was already running at close to capacity. Future research that evaluates the expected payout from redundant capacity in slaughter and/or cold storage may be justified.

## 4 | THE U.S. TURKEY INDUSTRY

The closure of much of the U.S. food service sector—that is, restaurants, school lunch programs, and cafeterias—had a severe impact on U.S. turkey producers. They were impacted, in part, because turkey producers are vertically integrated: owning the slaughter plants through retail branding and distribution. The food service sector is a high margin, value-added, year-round opportunity for the turkey industry. Faced with the loss of this sector of the economy, turkey producers adjusted by selling more through the lower margin retail sector, reducing prices for remaining food sector customers and storing the remainder of production.

Unlike the pork market, there is no futures contract on turkey and it does not have mandatory price reporting. This severely limits the publicly available information for calculating the impact of the crisis on the industry. To fill in the data void, we conducted an anonymized survey of turkey companies in late April 2020. The five companies that responded represent 41.5% of U.S. turkey production. Each of the five companies filled out an information sheet describing the volume of business they lost in food service and the margin they capture on sales through food service. They also provided data on the volume shifted to retail and the margin on retail sales. We present the weighted average computations for the five companies below.

The average volume of turkey sold to food service in the year before the outbreak was approximately 7.6 million pounds per month. The average margin on food service sales was $0.45 per pound. These five firms reported that they kept about one-third (2.73 million pounds/month) of this food sector business over the course of the food service restrictions, though with a slightly lower margin of $0.37 per pound. They shifted about one-third (2.95 million pounds/month) of the former food service business to retail, and earned a negative margin on this retail business of $0.125 per pound. The remainder was stored to prepare for the reopening of food service, some of which has occurred since the survey was taken.[6]

Before the pandemic, the five companies averaged a total gross margin on the food service business of $1.56 million/month. Given the mandated food service restrictions due to COVID-19, and with the same production volume, the new average total gross margin on food service was $265,000 per month and for retail was a loss of $360,000 per month, with still roughly one-third of the product being held in storage, accruing costs. Instead of a positive average gross margin of $1.56 million/month, the companies lost $95,700 per month. Total damage across the five companies was estimated at $8.28 million/month in the April–May time period. Scaling these results up to

[6]USDA storage data showed that frozen turkey stocks rose in March at the normal seasonal rate and then were stable in April even though stocks normally build in this month. Therefore, the data are not in line with the survey responses. We think that sales of frozen whole birds at retail outlets had a greater impact on stocks than the buildup of value added turkey products in the warehouses of turkey processors. See https://www.nass.usda.gov/Charts_and_Maps/Livestock_Cold_Storage/turkeys.php.

reflect the entire U.S. turkey industry, we estimate industry-wide losses of approximately $19.95 million/month during the COVID-19-induced restaurant and school closures.

Interviews with company executives suggest the industry was slow to switch away from food service because packaged turkey destined for food service comes in packages much larger than those demanded at retail outlets. In addition, food service packages contain "not for retail sale" labeling. These issues of product sizing and labeling had to first be addressed for turkey to shift from food service to retail. The scale of losses and the lack of positive returns on the retail side suggest that companies will likely look to increase cold storage capacity to better prepare for new or ongoing food service closures. They will also evaluate procedures to allow rapid changes in packaging and labeling.

## 5 | THE U.S. EGG INDUSTRY

The egg industry is divided into two distinct sectors: the shell egg sector, which produces eggs for the retail (mainly grocery store) market, and the breaker egg sector, which produces eggs that are broken and processed for the food manufacturer and food service industries. The procedures for production and the rules and regulations for food safety are different for the two sectors. Thus, early in the supply chain—certainly much earlier than in pork and turkey—the egg production process specializes based on the sector the eggs will enter. Because of the different regulations, moving eggs between the two sectors is challenging and generally asymmetric. It is easier to shift shell eggs into the breaker egg market than to move breaker eggs into the shell egg market. Farms that produce shell eggs must comply with specific safety rules from the FDA (e.g., *Escherichia coli* testing) that farms producing breaker eggs do not have to meet (FDA, 2009). This means that shell eggs can be redirected to the breaker egg market with no to relatively small production changes, but breaker eggs cannot be redirected to the shell egg market unless the farm meets or changes to meet FDA standards.

The food service related shifts in food consumption had very direct impacts on the egg industry. For an in-depth accounting of the COVID-19 impacts to the egg industry and the associated price dynamics, see Malone et al. (2020). Restaurant and school closures took out the largest outlets for breaker eggs, reducing their market dramatically. At the same time, the increase in FAH consumption meant sizable increases in grocery store sales and drove shell egg prices much higher than usual. Figure 11 shows the impacts to shell and breaker egg prices over the course of the last 2 years. Shell eggs usually capture a price twice as high as breaker eggs. Early in the COVID-19 outbreak (early March) both types of eggs experienced a surge in prices as individuals stocked up in preparation for stay-at-home orders and food service closures. However, as the movement restrictions set in, shell egg prices continued to skyrocket with increased grocery sales, while breaker egg prices began to retreat with the losses in the FAFH markets. By early April, shell eggs were trading at prices over six times higher than breaker eggs.

On April 3, 2020, the FDA issued a temporary exemption to ease the transition of breaker eggs into the shell egg market, while still meeting food safety concerns (FDA, 2020). While the ability to shift some eggs from breaker to shell did help reduce breaker egg supplies and boost shell egg supplies, market conditions were still troublesome for breaker eggs. Throughout the month of April, prices dropped for both types of eggs. Even though breaker egg supplies were reduced, breaker egg demand shrunk even faster with the restaurant and school closures. Breaker egg prices declined by 75% within a month. Shell eggs saw a similar decline but were still priced at four to five times the level for breakers. By the beginning of May, shell egg prices returned to pre-COVID-19 levels, but breaker egg prices were 33% below pre-COVID-19 levels. Throughout May and June, as restrictions were lifted and some restaurants were able to reopen, breaker egg prices began to recover, while shell egg prices held steady. Over time, the price gap between the egg types has returned to a more normal relationship, with breaker eggs pricing at roughly one-half of shell eggs.

Interviews with egg industry personnel point to upcoming changes within the industry that may represent a first step toward building resiliency into an efficient and coordinated system. One breaker egg industry executive that was interviewed for this study said that he planned to add *E. coli* testing capabilities in his breaker egg barns to

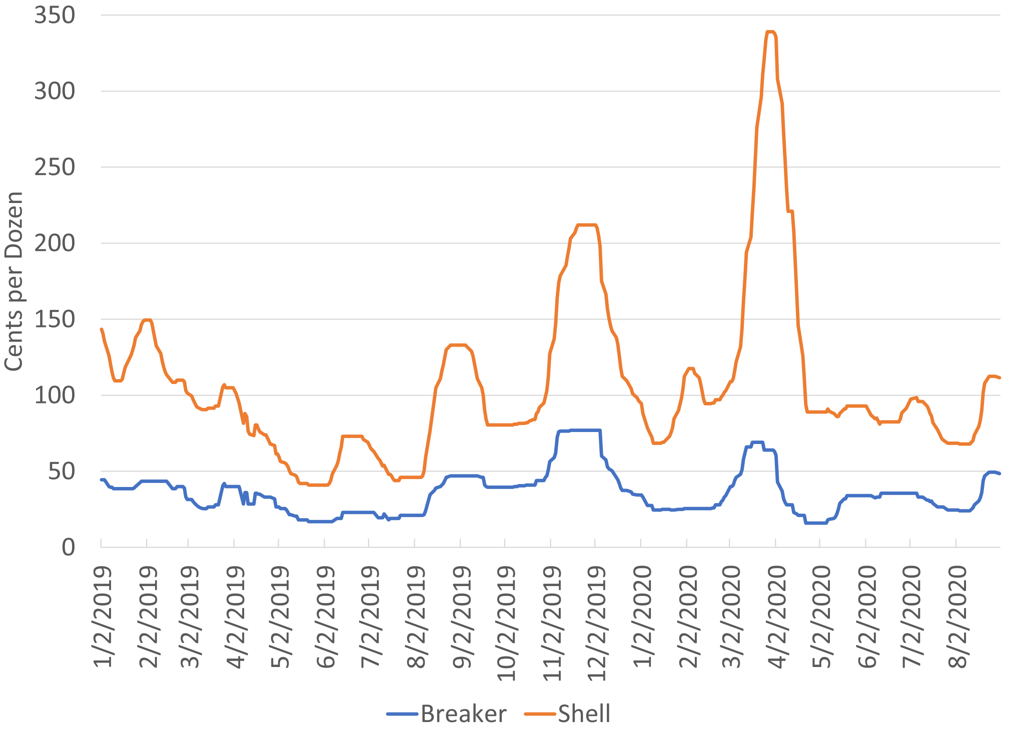


**FIGURE 11** Daily Midwest egg prices, 2020. Data Source: USDA-AMS. Notes: January 1, 2019 through August 31, 2020 [Color figure can be viewed at wileyonlinelibrary.com]

allow for an easier transition should the food service sector be forced to close again. He also said that mechanical egg breakers are integrated into the barns and that he was considering moving the breakers to a location just outside the barn. Under the current production system, the product that comes out of the barns consists of bulk, liquid eggs. A possible change under consideration is to have all barns produce shell eggs, some of which are then moved to a breaker facility.

## 6 | DISCUSSION AND SUMMARY

Our U.S. food supply chains are efficient and rely on a high degree of temporal coordination. In normal times, these characteristics have benefits along the supply chains, from producers through to consumers. However, the COVID-19-related events in the spring of 2020 and our experiences within the U.S. food supply chains highlight rigidities in our food production system that, when stressed, result in higher consumer prices, lower producer prices, and imbalances in food markets. While common challenges existed, the experiences for the pork, turkey, and egg industries were unique, we believe owing to the structure of each of the supply chains. In particular, where in the supply chain end-market specialization occurs may play a role in the consequences of large-scale shocks and suggest innovations in the supply chains that can enhance resiliency.

The notion of building "resiliency" into efficient production and processing systems quickly rose to the surface as the pandemic unfolded. One definition of supply chain resiliency is "the ability of a supply chain to both resist disruptions and recover operational capability after disruptions occur" (Melnyk et al., 2015). Focusing on building resiliency in ag and food supply chains is not to suggest that they lack resiliency in all dimensions—we know from past interruptions and even this one that market price-based coordination between supply chain stakeholders did occur and innovation and regulatory intervention helped. Still, there are places we can look within our food supply chains for improvements in resiliency. One is in buyer–seller relationships. Hobbs' (2020) assessment of the pandemic's impact on food supply chains includes an important discussion on the role and consequence of buyer–supplier relationships in economic downturns. Work in this area suggests that buyer–supplier relationships in highly competitive markets (e.g., retail groceries) are prone to failure during challenging economic conditions because the relationships are transactional and characterized by high levels of information asymmetry (Matopoulos et al., 2019). On the other hand, supply chains designed with more collaboration and long-term relationships fare better during stressed periods (Cao & Zhang, 2011; Leat & Revoredo-Giha, 2013; Matopoulos et al., 2019). This suggests future investigations into the performance of our food supply chains across industries with varying structures of buyer–supplier relationships. Did the industries with more collaboration fare better, and can the pork industry learn from this?

Relationship structures are just one place to look for improving resiliency. Future research should consider other opportunities as well. When processing capability is the main bottleneck (as was the case in pork), does flexibility derive from more but smaller production or storage facilities, or are perhaps larger facilities preferred? Labor capacity and utilization are another area for investigation. The Canadian Food Inspection Agency developed a "business continuity plan" to ensure processing plants continue to operate by shifting workers from lower risk areas to higher-risk ones (Canadian Food Inspection Agency, 2020; Hobbs, 2020). What can our industries who suffered from labor shortages due to illness learn from this strategy?

We learned from the experience in the turkey industry that research and innovation on flexibility in product sizing and packaging may lead to more efficient and timely shifts between the food service and retail sectors if we experience another reduction in food service activity. The FDA and regulatory agencies play an important role as well. Turkey and other products intended for the food service sector are labeled such that they cannot be sold in retail and grocery markets. Is there is an opportunity, and what are the consequences, of emergency orders that relax, for example, labeling requirements to allow food to move more easily between FAH and FAFH markets?

The case of eggs was unique because the egg industry specializes very early in the supply chain—at the barn level—based on different FDA regulations governing breaker and shell egg processing. There is emerging anecdotal evidence that producers are investing in technologies to allow them to switch sectors more easily, a prime example of innovations that increase flexibility and therefore resiliency.

There are two key take-aways from our assessment of the pork industry that future research will undoubtedly carry forward. The first is of importance in understanding pricing within contracts between producers and packers. The market evidence suggests that shifting to contracts where pricing is based on the value of carcass may be a more efficient risk mitigation strategy for packers and producers. The second is of the value of collaboration between veterinarians, animal nutritionists, university extension, and industry. During COVID-19, the industry worked together to find ways to hold the weight of hogs and increase stocking densities on the farm to mitigate the destruction of animals. These and other experiences give rise to the potential for resiliency-enhancing plans or innovations in the face of a major disruption. A key challenge for this study, future research, and for the industries contemplating making structural changes is that we do not know the probability of another event of this type.

## ACKNOWLEDGMENTS

The authors thank John Crespi at Iowa State University for his insights on agricultural supply chains. This study is funded by the USDA National Institute of Food and Agriculture Rapid Response to Novel Coronavirus (SARS-CoV-2) Impacts Across Food and Agricultural Systems Award 2020-68006-32790. The contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA or NIFA.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## ORCID

*Dermot J. Hayes* http://orcid.org/0000-0002-6278-7238
*Lee L. Schulz* https://orcid.org/0000-0003-3492-4431
*Chad E. Hart* https://orcid.org/0000-0002-6359-2483
*Keri L. Jacobs* https://orcid.org/0000-0001-8810-2674

## REFERENCES

Balistreri, E. J., Hart, C. E., Hayes, D. J., Li, M., Schulz, L., Swenson, D. A., Zhang, W., & Crespi, J. M. *The Impact of the 2018 Trade Disruptions on the Iowa Economy*. CARD Policy Brief 18-PB 25, September 2018.

Barry, P. J., Sonka, S. T., & Lajili, K. (1992). "Vertical coordination, financial structure, and the changing theory of the firm". *American Journal of Agricultural Economics*, *74*, 1219–1225.

Canadian Food Inspection Agency. 2020. *Coronavirus disease (COVID-19): CFIA information for industry*. Canadian Food Inspection Agency, Government of Canada. https://www.inspection.gc.ca/covid-19/cfia-information-for-industry/eng/1584462704366/1584462704709

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and performance. *Journal of Operations Management*, *29*(3), 163–180.

Chopra, S., & Sodhi, M. S. (2004). Managing risk to avoid supply-chain breakdown. *MIT Sloan Management Review*, 53–61.

Cotterill, R. W. (2001). Neoclassical explanations of vertical organization and performance of food industries. *Agribusiness*, *17*, 33–57.

Cowley, C. "COVID-19 Disruptions in the U.S. Meat Supply Chain." Main Street Views. Federal Reserve Bank of Kansas City; 2020. https://kansascityfed.org/research/regionaleconomy/articles/covid-19-us-meat-supply-chain?sm=rs080320

Crespi, J. M., & Saitone, T. L. (2018). Are cattle markets the last frontier? Vertical coordination in animal-based procurement markets. *Annual Review of Resource Economics*, *10*(1), 207–227.

Crespi, J. M., Saitone, T. L., & Sexton, R. J. (2012). Competition in US farm product markets: Do long-run incentives trump short-run market power? *Applied Economic Perspectives and Policy*, *34*, 669–695.

Elbakidze, L., Highfield, L., Ward, M., McCarl, B. A., & Norby, B. (2009). Economics analysis of mitigation strategies for FMD introduction in highly concentrated animal feeding regions. *Applied Economic Perspectives and Policy*, *31*, 931–950.

Franken, J. R. V., & Parcell, J. L. (2012). Evaluation of market thinness for hogs and pork. *Journal of Agricultural and Applied Economics*, *44*(4), 461–475.

Goodhue, R., & Rauser, G. C. (2001). Production and marketing. In B.Gardner, & G. Rauser (Eds.), *Handbook of agricultural economics*. Elsevier Science B.V.

Hennessy, D. A. (1996). Information asymmetry as a reason for food industry vertical integration. *American Journal of Agricultural Economics*, *78*, 1034–1043.

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics*, *68*, 171–176.

Lawrence, J. D., Rhodes, V. J., Grimes, G. A., & Hayenga, M. L. (1997). Vertical coordination in the US pork industry: Status, motivations, and expectations. *Agribusiness*, *13*, 21–31.

Leat, P., & Revoredo-Giha, C. (2013). Risk and resilience in agri-food supply chains: The case of the ASDA PorkLink supply chain in Scotland. *Supply Chain Management*, *18*(2), 219–231.

Lusk, J. (2020). *Impacts of coronavirus on food markets*. Blogpost. http://jaysonlusk.com/blog/2020/3/16/impacts-of-coronavirus-on-food-markets

Malone, T., Schaefer, K. A., & Lusk, J.Unscrambling COVID-19 Food Supply Chains (August 10, 2020). https://doi.org/10.2139/ssrn.3672018

Martinez, S. W. (2002). *Vertical coordination of marketing systems: Lessons from the poultry, egg, and pork industries* (Agricultural Economic Report No. 807). U.S. Department of Agriculture, Economics Research Service.

Matopoulos, A., Didonet, S., Tsanasidis, V., & Fearne, A. (2019). The role of perceived justice in buyer–supplier relationships in times of economic crisis. *Journal of Purchasing and Supply Management*, *25*(4), 100554.

McBride, W. D., & Key, N. (2003). *Economic research service. U.S. Department of Agriculture* (Agricultural Economic Report No. 818). https://www.ers.usda.gov/webdocs/publications/41510/17861_aer818_1_.pdf?v=7745.8

McEwan, K., Marchand, L., Shang, M., & Bucknell, D. (2020). Potential implications of Covid-19 on the Canadian pork industry. *Canadian Journal of Agricultural Economics*, *68*(2), 201–206.

Melnyk, S. A., Closs, D. J., Griffs, S. E., Zobel, C. W., & MacDonald, J. R. (2015). Understanding supply chain resilience. Supply Chain News. https://www.supplychain247.com/article/understanding_supply_chain_resilience

Meyer, S. (2016). USDA Hogs & Pigs: A very tough fall is coming. National Hog Famer. https://www.nationalhogfarmer.com/marketing/usda-hogs-pigs-very-tough-fall-coming

Meyer, S. (2020). Even a grim week has flicker of brightness. National Hog Farmer. https://www.nationalhogfarmer.com/marketing/even-grim-week-has-flicker-brightness

Moschini, G., & Meilke, K. D. (1992). Production subsidy and countervailing duties in vertically related markets: The Hog-Pork case between Canada and the United States. *American Journal of Agricultural Economics*, *74*, 951–961.

Peña-Lévano, L., Melo, G., & Burney, S. (2020). Theme overview: COVID-19 and the agriculture industry: Labor, supply chains, and consumer behavior. *CHOICES*, 3. https://www.choicesmagazine.org/choices-magazine/theme-articles/covid-19-and-the-agriculture-industry-labor-supply-chains-and-consumer-behavior/theme-overview-covid-19-and-the-agriculture-industry-labor-supply-chains-and-consumer-behavior

Pendell, D. L., Leatherman, J. C., Schroeder, T. C., & Alward, G. S. (2007). The economic impacts of a foot-and-mouth disease outbreak: A regional analysis. *Journal of Agricultural and Applied Economics 'Special Issue'*, *39*, 13–33.

Pendell, D. L., Marsh, T. L., Coble, K. H., Lusk, J. L., & Szmania, S. (2015). Economic assessment of FMDv releases from the National Bio and Agro Defense Facility. *PLoS One*, *10*, e0129134.

Royer, J. S., & Rogers, R. T. (Eds.). (1998). *The industrialization of agriculture. Vertical coordination in the U.S. food system*. Ashgate Publishing Ltd.

Schlenker, W., & Villas-Boas, S. B. (2009). Consumer and market responses to Mad Cow disease. *American Journal of Agricultural Economics*, *91*, 1140–1152.

Schroeder, T. C., Pendell, D. L., Sanderson, M., & McReynolds, S. (2015). Economic impact of alternative FMD emergency vaccination strategies in the Midwestern United States. *Journal of Agricultural and Applied Economics*, *47*, 47–76.

Schroeder, T. C. (1988). Price linkages between wholesale and retail pork cuts. *Agribusiness*, *4*(4), 359–369.

Schroeder, T. C., & Ward, C. E. (2000). "*Price Discovery Issues and Trends In Cattle And Hog Markets*." 2000 Annual Meeting, June 29–July 1, 2000, Vancouver, British Columbia 36418, Western Agricultural Economics Association.

Sexton, R. J., & Lavoie, N. (2001). Food processing and distribution: An industrial organization approach. In B. Gardner, & G. Rauser (Eds.), *Handbook of agricultural economics*. Elsevier Science B.V.

The White House. (2020). "Executive Order on Delegating Authority Under the DPA with Respect to Food Supply Chain Resources During the National Emergency Caused by the Outbreak of COVID-19." https://www.whitehouse.gov/presidential-actions/executive-order-delegating-authority-dpa-respect-food-supply-chain-resources-national-emergency-caused-outbreak-covid-19/

Tonsor, G., & Schulz, L. (2020). "COVID-19 Impacts on the Meat Processing Sector." Economic Impacts of COVID-19 on Food and Agricultural Markets—CAST Commentary. In J. L. Lusk and J. Anderson (eds.). Council for Agricultural Science and Technology. https://www.cast-science.org/wp-content/uploads/2020/06/QTA2020-3-COVID-Impacts.pdf

U.S. Department of Agriculture, Agricultural Marketing Service (USDA-AMS). (2017). "USDA Market News Swine Report Review." https://www.ams.usda.gov/sites/default/files/media/LPSNationalPorkBoardPresentation20170907.pdf

U.S. Department of Agriculture, Economic Research Service. (2020). "Eating-out expenditures in May were 37 percent lower than May 2019 expenditures." *Charts of Note Series*. https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=99064

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). (2019). 2017 census of agriculture, United States summary and state data, *Geographic Area Series*: *Vol. 1*, *Part 51*. https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). (2020). *Livestock Slaughter Annual Summary*. https://usda.library.cornell.edu/concern/publications/r207tp32d

U.S. Food and Drug Administration (FDA). (2020). "*FDA Provides Temporary Flexibility Regarding the Egg Safety Rule During COVID-19 Pandemic While Still Ensuring the Safety of Eggs*." https://www.fda.gov/food/cfsan-constituent-updates/fda-provides-temporary-flexibility-regarding-egg-safety-rule-during-covid-19-pandemic-while-still

U.S. Food and Drug Administration (FDA). (2009). "*Prevention of Salmonella enteritidis in Shell Eggs During Production, Storage, and Transportation: Final Rule*." https://www.govinfo.gov/content/pkg/FR-2009-07-09/pdf/E9-16119.pdf

Vercammen, J., & Schmitz, A. (2001). Marketing and distribution. In B. Gardner, & G. Rauser (Eds.), *Handbook of agricultural economics*. Elsevier Science B.V.

## AUTHOR BIOGRAPHIES

**Dermot Hayes** is Charles F. Curtiss Distinguished Professor in Agriculture and Life Sciences in the Department of Economics and Professor and Pioneer Hi-Bred International Chair in Agribusiness in the Ivy School of Business at Iowa State University. He obtained his Ph.D. in Agricultural and Resource Economics at the University of California at Berkeley in 1986. His areas of expertise include U.S. farm policy and international agricultural trade, agribusiness, crop insurance, financial derivatives, and the potential impact of China on commodity markets.

**Lee L. Schulz** is an associate professor and extension economist in the Department of Economics at Iowa State University, Ames, Iowa. He earned a B.S. in Agricultural Business from the University of Wisconsin-River Falls in 2006, a M.S. in Agricultural Economics from Michigan State University in 2008, and a Ph.D. in Agricultural Economics from Kansas State University in 2012. His research focuses on livestock economics and markets.

**Chad E. Hart** is a professor and extension economist in the Department of Economics at Iowa State University, Ames, Iowa. He received his B.S. in Economics in 1991 from Southwest Missouri State University and his Ph.D. in Economics and Statistics in 1999 from Iowa State University. Hart's research is in the areas of agricultural markets, risk management, and whatever interesting subject might present itself.

**Keri L. Jacobs** is an associate professor, extension economist, and Iowa Institute for Cooperatives Endowed Professor in the Department of Economics at Iowa State University, Ames, Iowa. She received a B.S. in 1996 from Coe College in Cedar Rapids, Iowa and a Ph.D. in 2010 from North Carolina State University. Jacobs' research is in the area of cooperative and agribusiness economics.

**How to cite this article:** Hayes DJ, Schulz LL, Hart CE, Jacobs KL. A descriptive analysis of the COVID-19 impacts on U.S. pork, turkey, and egg markets. *Agribusiness*. 2021;37:122–141.
https://doi.org/10.1002/agr.21674