



COVID-19 Working Paper: Changes in Regional Hog Slaughter During COVID-19

Samantha L. Padilla, Lee L. Schulz, Kate Vaiknoras, Matthew J. MacLachlan

This paper is published through USDA, Economic Research Service's (ERS) COVID-19 Working Paper series. This temporary Working Paper series is designed to publicly release preliminary analyses relevant to the impacts of the COVID-19 pandemic on agriculture, food, the environment, and rural America in a timely manner. ERS' COVID-19 Working Papers have not undergone the review and editorial process generally accorded official ERS publications, but ERS economists and social scientists reviewed them through an expedited process. The findings and conclusions in this COVID-19 Working Paper are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

Abstract

This working paper describes how COVID-19 affected the pork packing industry, gives an overview of this industry, and measures changes in regional slaughter volumes in 2020. We find different effects of COVID-19 across regions. Some regions experienced a prolonged decline in hog slaughter compared with 2019, while in other regions sharp declines only lasted a few weeks. Slaughter counts in the major pork-producing regions declined for three weeks at the end of April and early May but recovered to 2019 levels by June 2020. Minor processing regions had mixed reactions to the pandemic. For instance, Region 2 (New Jersey and New York) experienced a large decline in slaughter, but, unlike major processing regions, the shock persisted throughout the year—slaughter rates were lower than 2019 levels. Overall, most regions in 2020 had increases in total slaughter compared with 2019, suggesting the industry suffered at the beginning of the pandemic but adjusted production and at least partially recovered.

Keywords: Pork, pork processing, hogs, hog slaughter, coronavirus, COVID-19, supply chain

Acknowledgments

We thank Monte Vandever and Jayson Beckman of USDA, Economic Research Service (ERS) for providing technical reviews of this paper. Finally, we thank Kelly Maguire, Jeff Chaltas, Jana Goldman, and Adele Wilcoxon of USDA, ERS for assistance with the publication process.

Use of commercial and trade names does not imply approval or constitute endorsement by USDA.

To ensure the quality of its research reports and satisfy governmentwide standards, ERS requires that all research reports with substantively new material be reviewed by qualified technical research peers. This technical peer review process, coordinated by ERS' Peer Review Coordinating Council, allows experts who possess the technical background, perspective, and expertise to provide an objective and meaningful assessment of the output's substantive content and clarity of communication during the publication's review.

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at [How to File a Program Discrimination Complaint](#) and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

Table of Contents

Summary	4
Introduction	6
The Pork Processing Industry: Background and Current Structure	9
Overview of COVID-19 and the Pork Supply Chain.....	9
Types of Pork-Packing Plants	10
Structure of Pork-Packing Sector.....	11
Data and Summary Statistics	13
Changes in Regional Slaughter Rates in 2020	18
Major Pork-Producing Regions—3, 5, 6, 7.....	18
Other Regions—1, 2, 9, and 10.....	20
Conclusion	23
References	24
Appendix	26
Appendix A	26
Appendix B	27
Appendix C	29

Summary

The Coronavirus (COVID-19) pandemic impacted production in pork processing plants across the United States, and these effects reverberated throughout the supply chain. This Working Paper describes how COVID-19 affected the pork packing industry, gives an overview of this industry, and measures changes in regional slaughter volumes in 2020. We find different effects of COVID-19 across regions. Some regions experienced a prolonged decline in hog slaughter compared with 2019, while sharp declines in other regions only lasted a few weeks. For example, the greatest percentage decrease in slaughter occurred in the region that comprises New York and New Jersey, which extended well beyond the start of the pandemic. In contrast, slaughter counts in the major pork-producing region that comprises Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin, declined for three weeks at the end of April and early May, but it was generally above 2019 counts for the remainder of 2020. The region with the largest hog production, which is comprised of Iowa, Kansas, Missouri, and Nebraska—had measurable declines in output in April and May, but output rebounded to 2019 levels by June. These contrasting results could be the result of existing differences among processing plants within regions, but further research is necessary to quantify the relationship between plant characteristics and changes in slaughter volumes.

What Is the Issue?

Beginning in April 2020, increasing COVID-19 infections among workers at pork processing facilities led many plants to slow production and some to temporarily shut down. Because of the difficulties surrounding pork production during the pandemic, there have been calls to examine the effects of COVID-19 on the meat industry and the resilience of the pork supply chain. Thus far, the discussion related to pork processing in 2020 has centered on plant-specific closures and aggregate slaughter volumes. However, the pandemic did not equally affect U.S. regions. In this report, we describe the structure of the pork processing industry, explore regional variation in slaughter in 2020 using year-over-year comparisons with 2019, and discuss the resiliency of the industry. In this study, we define resilience as a region's ability to match or surpass 2019 weekly slaughter volumes in 2020.

What Did the Study Find?

COVID-19 affected each region's hog slaughter volume in the beginning months of the pandemic. However, the magnitude of the change in slaughter and the trajectory of recovery differed across regions.

- In the first three months of the pandemic, major processing States in Midwest regions including Region 5 (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin); and Region 7 (Iowa, Kansas, Missouri, and Nebraska) experienced a sharp weekly decline (30–40 percent) in slaughter compared with 2019 rates. By June, processing recovered and slaughter for the remainder of the year was generally on par with 2019 levels.

- Overall, slaughter in 2020 for Region 5 and Region 7 was 5 percent and 3 percent higher, respectively, than in 2019. Combined, these two regions account for about three-quarters of hog slaughter in the United States.
- Region 3 (Delaware, Maryland, Pennsylvania, Virginia, and West Virginia) and Region 6 (Arkansas, Louisiana, New Mexico, Oklahoma, and Texas) account for roughly 4 percent of slaughter and, compared to other regions, have fewer medium and large packing plants. Both regions also experienced a decline in slaughter in May, but the relative reduction was smaller than the Midwest regions.
- Other regions with mostly smaller capacity packing plants experienced mixed changes in hog slaughter. Hog slaughter in Region 2 (New Jersey and New York) did not recover to levels above or equal to those in 2019 for the rest of the year, though the difference between 2019 and 2020 slaughter was never as large again as it was between April and June. COVID-19 had a seemingly stronger impact in this region; the correlation between slaughter rates and reported COVID-19 cases was negative and higher than the correlation in other regions.
- Region 9 (Arizona, California, Hawaii, and Nevada) saw a 14 percent increase in slaughter in 2020 compared to 2019. This region does not account for a large share of hog processing, but the large percentage increase in slaughter suggests the pandemic helped boost processing in this region.
- Regions with large pork processing plants recovered in a couple of months and slaughter rates steadily increased. Other regions with smaller plants did not recover faster than major processing regions, revealing that plant size might not be the only characteristic influencing resiliency.

Studies looking at the relationship between plant characteristics and the likelihood of changing processing capacity support a better understanding of the resiliency in the packing sector. While regional, descriptive analysis reveals important elements of the heterogeneous effects of COVID-19 on slaughter changes, it is not sufficient to determine causal effects. The assessment to be presented here is more demonstrative than definitive. The U.S. pork market was certainly impacted by a broad array of factors. Still, using economic theory and intuition, as well as available data, this Working Paper assesses the economic impacts in broad terms, providing a conceptual framework of the economic influence of COVID-19 on pork processing.

How Was the Study Conducted?

The study draws on two main sources of data to study changes in regional hog slaughter rates in 2020. Specifically, we used weekly and monthly regional slaughter volumes reported by U.S. Department of Agriculture, National Agricultural Statistics Service (NASS) and data on daily COVID-19 cases from the Centers for Disease Control and Prevention (CDC). The slaughter data originates from USDA's Food Safety and Inspection Service (FSIS) and weekly slaughter reports from USDA's Agricultural Marketing Service (AMS). We compared regional, weekly slaughter rates in 2020 to 2019 levels. Lastly, we used a listing of the major pork processing facilities developed by Meyer (2020) to further discuss changes in slaughter given the location and size of processing facilities in each region.

Introduction

For the first three months of 2020, slaughter volumes at U.S. federally inspected (FI) pork processing plants surpassed slaughter rates for the same period in 2019. During this time, futures prices fell while the cash market remained more stable (Hayes et al., 2020). Thus, the relatively high cash prices encouraged producers to market their hogs. Hayes et al. (2020) interprets this basis-driven signal as a forewarning of possible upcoming supply chain problems. Beginning in April 2020, increasing COVID-19 infections among workers at meat processing facilities led many plants to slow production and some to temporarily shut down. These shutdowns and reductions in daily production were because of labor shortages (Hart et al., 2020; Polansek and Sullivan, 2020), the implementation of the Centers for Disease Control and Prevention (CDC) safety protocols (CDC, 2021b; Parshina-Kottas et al., 2020), and State and local guidance. Slaughter rates fell at the end of April 2020 and reached a weekly low of 36 percent below 2019 levels (Lusk et al., 2021).

In response to the difficulties surrounding pork production during the pandemic, policymakers have called for an examination of the resilience of the pork supply chain (Hayes et al., 2021; Weersink et al., 2021) and the size and concentration in the packing industry (Lusk, 2020). Ribeiro and Barbosa-Povoa (2018) define resiliency of an industry as its ability to “prepare, respond and recover from disturbances and afterwards maintain a positive steady state operation in an acceptable cost and time.” In this study, we define resiliency as a region’s capacity to approximate or surpass 2019 slaughter volumes.

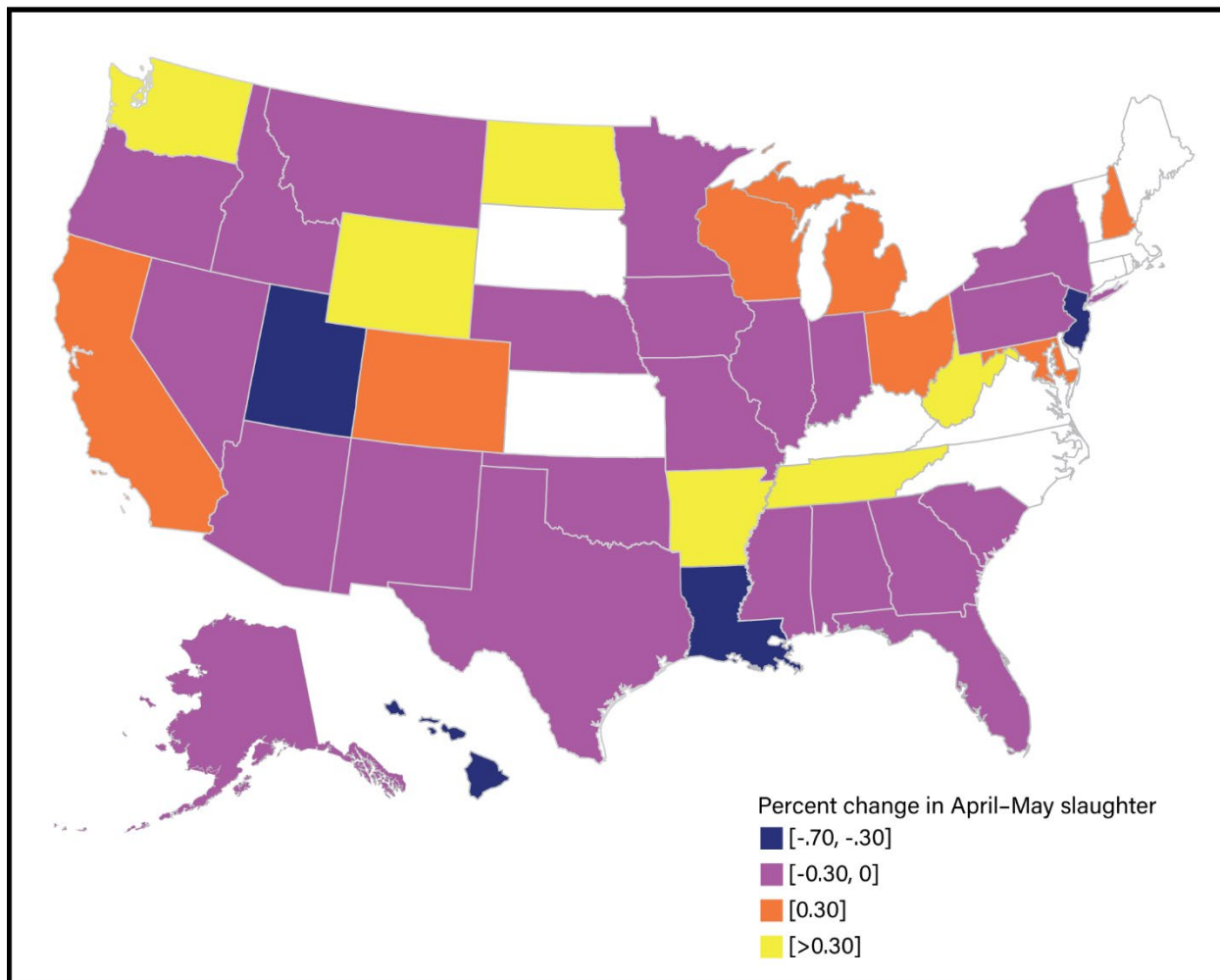
Much of the research related to COVID-19 and meat slaughter rates has focused on aggregate effects (Hayes et al., 2021; Lusk et al., 2021; Ramsey et al., 2021; Tonsor and Schulz, 2020b). However, inspection of year-over-year changes in slaughter rates reveals some variation across States. Figure 1 shows the average percentage change from 2019 to 2020 for slaughter during April and May. Some States, such as Washington and Wyoming, saw large increases in slaughter compared with 2019; other States, such as New York, Utah, and Louisiana, saw steep declines during the year. Large pork-producing States, such as Indiana, Minnesota, and Missouri, experienced more moderated declines in slaughter. The COVID-19 pandemic did not equally affect every region, and heterogeneity in State and regional slaughter levels merits closer examination to better understand the overall resiliency of the sector.

Specifically, there were three main reasons for exploring the effect of COVID-19 on regional hog slaughter. First, the temporary shutdowns of major processing plants were the primary driver of reduced slaughter levels, but large processors are not equally distributed across geographic regions in the United States. We can better explain the effects of the pandemic and the possible role of industry structure on resiliency via measuring regional changes in slaughter and incorporating the number of plants by size in each region. Second, there is a correlation between COVID-19 cases and changes in slaughter at the beginning of the pandemic. However, the level of COVID-19 differed across regions and therefore it is possible year-to-year changes in slaughter varied across regions because of the variation in the COVID-19 shock. Lastly, while some regions (and States) do not have large pork processing operations, they experienced large, positive percentage changes in slaughter volumes from

2019 to 2020. For example, slaughter volumes in Arkansas and West Virginia increased drastically, suggesting these less-traditional processing locations picked up some production during the pandemic. Therefore, we looked at areas that are not major processing regions to fully describe the changes within the industry during the pandemic.

Figure 1

Percentage change in U.S. commercial hog slaughter between April–May 2020, baseline 2019



Notes: Slaughter levels for some States withheld to avoid disclosing data for individual operations or not applicable. These States appear white in the map.

Source: USDA, National Agricultural Statistics Service Quick Stats 2019 and 2020 slaughter of hogs, measured in head.

This Working Paper describes the structure of the pork processing industry and the effect of COVID-19 on the sector. It explores regional variation in weekly slaughter in 2020 using year-to-year comparisons with 2019. We primarily use data reported by USDA’s National Agricultural Statistics Service (NASS) on weekly slaughter volumes and the CDC on daily COVID-19 cases to determine if there is a relationship between regional cases of COVID-19 and a reduction in slaughter capacity.

We find slaughter rates in every region decreased at the onset of the pandemic and the magnitude of the decline in slaughter rates varied across regions. For major pork processing regions, such as Regions 5 (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) and 7 (Iowa, Kansas, Missouri, and

Nebraska), the effect from the pandemic resulted in a deep decline in slaughter rates compared to year-earlier 2019 levels, but the persistence of the shock was short-lived. By June, slaughter rates in both regions surpassed those observed in June 2019. Combined, these two regions have most medium and large plants and jointly accounted for 73 percent of total slaughter in 2020.

The increase in slaughter after June 2020 suggests major processing plants were not initially prepared for further labor shortages induced by the COVID-19 pandemic, but quickly adjusted to restore pre-pandemic pork processing levels. This adjustment was achieved through a variety of strategies, including higher Saturday slaughter levels, worker wage bonuses, increased COVID-19 testing, the provisioning of personal protective equipment, increased worker spacing, the declaration of meat and poultry processing as essential infrastructure to help ensure continued operations, and the simplification of processing, including capturing less variety meats and by-products.

Minor processing regions had mixed reactions to the pandemic. For instance, Region 2 (New Jersey and New York) experienced a large decline in slaughter, but, unlike major processing regions, the shock persisted throughout the year—slaughter rates were lower than 2019 levels. However, Region 9 (Arizona, California, Hawaii, and Nevada), also not a major processing region, had higher slaughter rates in 2020 compared with 2019.

Overall, most regions in 2020 had increases in total slaughter compared with 2019, suggesting the industry suffered at the beginning of the pandemic but adjusted production and at least partially recovered. Regions with large pork packing plants demonstrated the transitory nature of the pandemic. Production quickly rebounded from the drop during the first months of the pandemic. Slaughter in regions with smaller plants did not recover faster than regions with larger plants, revealing that physical capacity might not be the major characteristic influencing resiliency. Studies looking at the relationship between plant characteristics and the likelihood of changing processing capacity are necessary to better understand what influences resiliency in the packing sector.

Policymakers and academics have expressed interest in understanding the role and resilience of smaller pork processing plants (and regions) and their vulnerability when some negative event occurs (Pitt, 2021). This study documents what happened to minor pork producing regions and their recovery trajectory through 2020. While the assessment presented here is more demonstrative than definitive, the COVID-19 pandemic certainly affected the U.S. pork market. The regional, descriptive analysis reveals important elements of the differing effects of COVID-19 on hog slaughter. To better understand this heterogeneity, we explore the possibility that different levels of shock from COVID-19 (which were not necessarily identical across regions) were somewhat related to existing differences among regions, such as the number and size of plants in the area. However, our analysis and the data used in this report do not allow for the determination of which characteristics have causal effects on resiliency and production.

The Pork Processing Industry: Background and Current Structure

In this section, we discuss the broad effects of the pandemic, the types of processing plants within the U.S. pork industry, and the current structure of that industry. For our purposes, the size of the operation characterizes industry structure.

Overview of COVID-19 and the Pork Supply Chain

In the United States, hog production is regionally concentrated with pork processing plants located near hog farmers. This proximity allows for timely delivery of hogs to the packing plant. If the COVID-19 pandemic and associated restrictions disrupted the normal delivery of hogs to packing plants and growers held onto finished hogs, then they incurred additional variable costs. Furthermore, if carcass quality was compromised, there was an associated risk that the hogs' value would decline. When pork processing plants shut down or otherwise reduced daily slaughter capacity because of COVID-19, some hog farmers were unable to send their hogs to slaughter. Instead, they had to adjust their production schedules, find alternate buyers, and hold hogs longer than expected (Schulz, 2020). In addition, hogs are raised to have a specific weight, ideal for slaughter plants with machinery honed to process hogs of precise weights. Hogs above certain weight specifications cannot be processed at slaughter facilities because of constraints on the equipment and concerns with worker safety (NPPC, 2020).

Going into 2020, the USDA projected the meat industry would produce a record volume of pork¹ (USDA, 2020) in response to increasing consumer demand (Tonsor and Schulz, 2020a). In early 2020, slaughter rates exceeded those in early 2019 resulting in large² inventories of pork in the United States at the beginning of the pandemic to mitigate potential early supply disruptions resulting from plants completely shutting down. Because processed product reaches the consumer two weeks after slaughter, high inventory buffered the effects of increases in retail purchases that occurred at the start of the pandemic. The industry also began adjusting production practices before the U.S. outbreak. These adjustments, including modifying hog diets and increasing stocking densities, reduced the negative impacts of supply chain disruptions (Hayes et al., 2021). However, packing plants were already operating near maximum capacity at the onset of the pandemic and had a limited ability to absorb additional production when a neighboring plant shut down (Tonsor and Schulz, 2020a). The closer that packing plants operate to their physical and operational capacity, the less room there is for the industry to absorb supply shocks and the greater the likelihood of backing up production for farmers (Ishmael, 2017). Operational capacity

¹ The January 2020 *World Agriculture Supply and Demand Estimates* projected total pork production at 28,659 million pounds, an increase from the 27,653 million pounds produced in 2019.

² Hog inventories were 4 percent higher entering 2020 than inventories beginning in 2019 (NASS, 2020b).

typically limits production more than physical capacity;³ in the case of COVID-19, worker shortages limited production capacity.

The uncertainty around the spread of COVID-19 and the lack of information on symptoms and mortality when contracting the virus encumbered effective disease prevention and control. As a result, large plants (which dominate the sector) became hotbeds for the virus and eventually shut down because of workforce absenteeism (Pellegrini, 2020). The uncertainty about the recovery trajectory of these plants also worsened the situation upstream for growers' production decisions and downstream impacts to food markets and pricing of common retail pork products.

Types of Pork-Packing Plants

All pork produced for retail sale and sold interstate in the United States must come from hogs slaughtered and processed under continuous federal inspection or State-inspected plants that can operate as federally-inspected facilities under the Cooperative Interstate Shipment (CIS) program.⁴ Inspection includes examination, checking or testing of a carcass and/or pork with regard to established government standards, as well as checking the facility for cleanliness, health of hogs, and quality of the pork produced. Pork from hogs slaughtered and processed under State inspection only—non-federal inspection (NFI)—is limited to intrastate commerce. Finally, hogs that are not for sale can be slaughtered at NFI custom-exempt plants. Custom-exempt slaughtered hogs and pork are not inspected, but the facilities must meet health standards.

Of the 129.93 million head of hogs slaughtered in the United States in 2019, 702,300 head, or 0.5 percent, were slaughtered under NFI (NASS, 2020a). In 2020, this percentage increased slightly: Total commercial hog slaughter was 131.563 million head, of which 780,800 head, or 0.6 percent, was NFI (NASS, 2021). The NFI slaughter increase from 2019 to 2020 suggests efforts to find alternative outlets outside the conventional or typical processing channels for market-ready hogs were quite limited in aggregate. Most of the 78,500-head NFI year-to-year increase occurred during the constraint to packing capacity in May (3,600 head) and the subsequent June (25,500 head), July (6,200 head), August (7,200 head), and September (7,300 head) period as the backlog of hogs was processed. These plants face many constraints, such as physical infrastructure, equipment, cooler space, and availability of skilled labor. In addition, to maximize value, the whole carcass must be sold. Smaller plants can have challenges accessing markets for some meat products, especially variety meats and by-products.

Finally, NASS provides data on hogs slaughtered on farms primarily for home consumption in its *Livestock Slaughter Annual Summary* report (NASS, 2021). These data exclude custom slaughter for

³ Physical capacity is the business' maximum productive capability while operational capacity indicates how much a facility is employing of their total capacity at any given time. Operational capacity is highly influenced by the supply of labor and therefore it is often the case there is a difference between physical and operational capacity.

⁴ Approximately, 91 non-federal inspection plants are part of the Cooperative Interstate Shipment program. The program is limited to plants in 27 States that have a Meat and Poultry Inspection program and maintain Food Safety and Inspection Service standards. There are also some additional requirements for plants to participate.

farmers at commercial establishments but includes mobile slaughtering on farms. In 2019, on-farm hog slaughter totaled 77,000 head, which was only 0.06 percent of total hog slaughter in 2019. Interestingly, in 2020, on-farm hog slaughter decreased to 76,000 head (0.06 percent of total hog slaughter).

Structure of Pork-Packing Sector

Total U.S. hog slaughter in federally inspected (FI) plants for 2019 was 129,210 million head, of which 62 percent were slaughtered at plants that processed over 3 million hogs per year. Of the 619 FI hog slaughter plants in the United States in 2019, 396 slaughtered fewer than 1,000 hogs annually, and these plants accounted for only 0.1 percent of total slaughter (table 1).

Similarly, in 2020, total hog slaughter at federally inspected plants was 130,782 million head in 2020, with 65 percent slaughtered in 17 plants that processed more than 3 million hogs per year. The U.S. had 621 federally inspected hog slaughter plants in 2020, compared with 619 in 2019. Of these, 389 plants slaughtered between 1 and 999 head of hogs during 2020, down 7 plants from 2019. Many smaller plants scaled up production in 2020. For example, in 2020, there were 133 federally inspected plants that slaughtered between 1,000 and 9,999 head of hogs, compared with 123 plants in 2019. Using simple category averages, this equates to plants going from slaughtering roughly 6 head per week to 53 head per week, based on slaughtering 51 weeks per year. Even with such expansion, however, plants slaughtering between 1 and 9,999 head still only processed 0.3 percent of the total FI hog slaughter.

Table 1

Hogs: Federally inspected plants and head slaughtered by size group in the United States, 2019 and 2020

Size group	2019				2020			
	Plants		Head (thousands)		Plants		Head (thousands)	
	Num.	Pct.	Num.	Pct.	Num.	Pct.	Num.	Pct.
1–999	396	64.0	125.4	0.1	389	62.6	127	0.1
1,000–9,999	123	19.9	337.9	0.3	133	21.4	359.1	0.3
10,000–99,999	39	6.3	1,529.4	1.2	37	6.0	1,367.5	1.1
100,000–249,999	18	2.9	2,967.6	1.3	17	2.7	2,762.0	2.1
250,000 - 499,99	7	1.1	2,501.0	1.9	6	1.0	2,038.6	1.6
500,000–999,999	3	0.5	2,074.1	1.6	6	1.0	3,898.8	2.9
1,000,000–1,999,999	6	1.0	7,849.1	6.1	5	0.8	7,127.2	5.5
2,000,000–2,999,999	12	1.9	31,794.8	24.6	11	1.8	28,046.1	21.4
3,000,000 +	15	2.4	80,031.5	61.9	17	2.8	85,055.9	65
Total	619		129,210.8		621		130,782.2	

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Livestock Slaughter Annual Summary, April 2021.

The meatpacking industry consolidated during the late 20th century, with large plants emerging to dominate the industry. Prior to the mid-1950s, most meatpacking plants were located near stockyards in urban areas with important railway hubs, such as Chicago and Kansas City. Beginning in the 1960s, the meatpacking industry entered a period of consolidation. Many smaller plants (fewer than 50 employees) began to exit the industry, while large plants with more than 1,000 workers located in rural areas (Broadway and Ward, 1990).

Until the mid-1980s, the U.S. hog industry consisted mainly of many small, independently owned, farrow-to-finish operations. Prior to the 1980s, pork packing plants underused the plant for 75 percent of the year (January–August) and maintained excess slaughter capacity to accommodate large, seasonal fall-winter (September–December) production (Haley, 2004). The race for scale economies (large plants produce at lower cost per head than small plants) was a key driver of consolidation (MacDonald and Ollinger, 2000) and changes in the structure of the industry in the latter decades of the 20th century. Plants that slaughtered more than a million hogs annually accounted for 38 percent of hog slaughter in 1977, but by 1997, large plants accounted for 87 percent of slaughter (MacDonald et al., 2000).

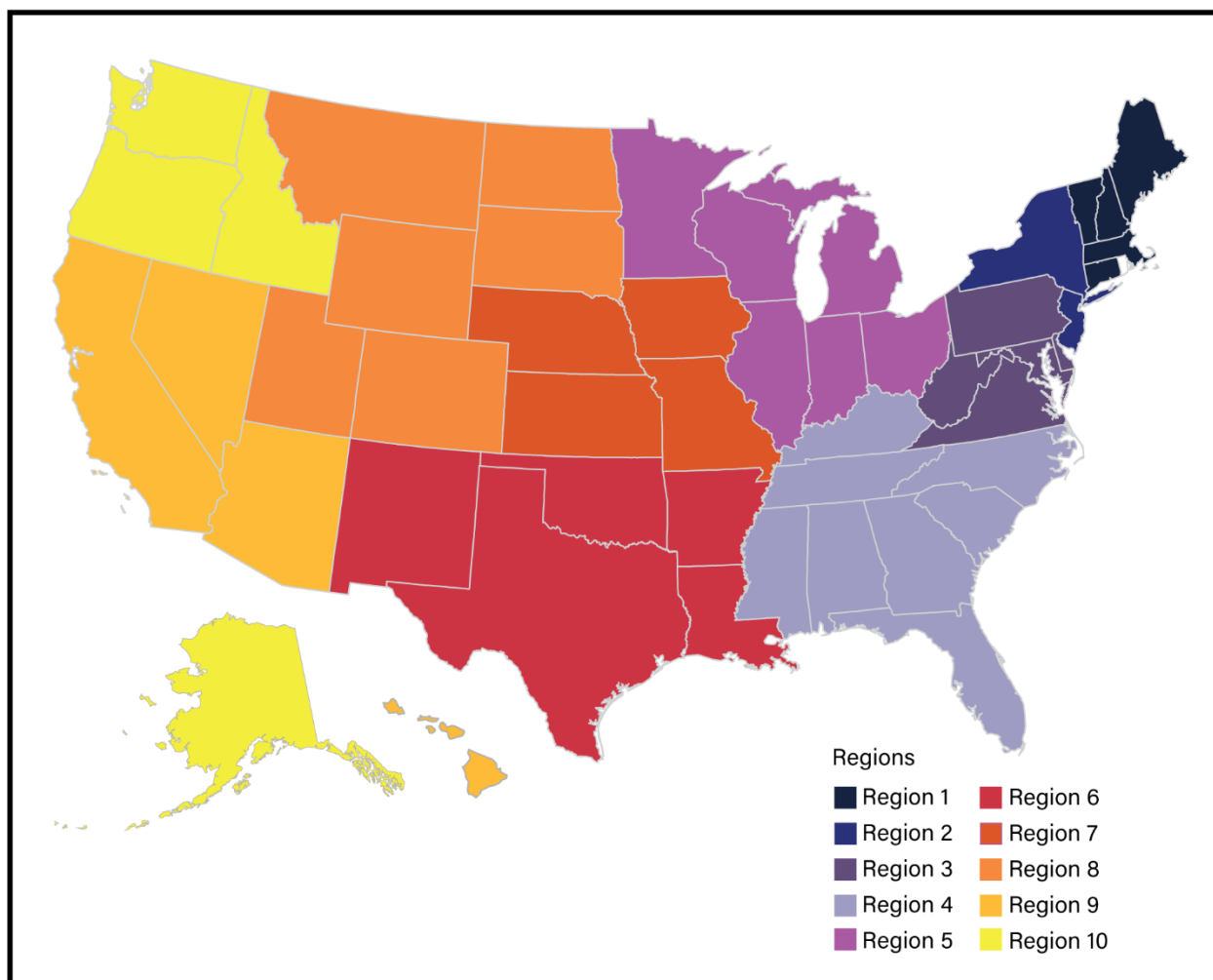
The current U.S. pork industry includes fewer, larger hog production and packing operations. Processing plants today produce close to capacity throughout the year. By maximizing slaughter throughout the year instead of having an “off-season” with underused plant facilities, processing operations can lower costs and specialize production (Haley, 2004). The economies of scale grew over time as changes in labor costs also began to favor large plants.

Data and Summary Statistics

We use two main datasets to study the 2020 changes in slaughter rates by region. First, USDA’s Agricultural Marketing Service (AMS) weekly and monthly slaughter data (accessed through the USDA’s National Agricultural Statistics Service (NASS) Quick Stats interface) and second, Centers for Disease Control and Prevention (CDC) data on daily COVID-19 cases. We use the 10 standard federal regions employed by NASS for our analysis. AMS also uses the standard federal regions in the USDA Market News Service report containing weekly livestock slaughter rates. Figure 2 below details which States are included in each region.⁵

Figure 2

Map of the standard federal regions



Note: States included in regions are as follows: Region 1—Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont; Region 2—New Jersey and New York; Region 3—Delaware, Maryland, Pennsylvania, Virginia, and West Virginia; Region 4—Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee; Region 5—Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin; Region 6—Arkansas, Louisiana, New Mexico, Oklahoma, and Texas; Region 7—Iowa, Kansas, Missouri, and Nebraska; Region 8—Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming; Region 9—Arizona, California, Hawaii, and Nevada; Region 10—Alaska, Idaho, Oregon, and Washington.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Quick Stats.

⁵ U.S. territories, such as Puerto Rico and American Samoa, are part of the standard federal region delineation but USDA, National Agricultural Statistics Service does not collect information on slaughter rates in these areas. For this reason, we omit these locations from figure 2 and the discussion detailed in this report.

Table 2 summarizes the total slaughter numbers in 2020 and 2019 by region. The percent change in total slaughter year to year demonstrates there is some variation in the changes between 2019 and 2020.

Region 2 had the largest, negative percent change in slaughter between 2019 and 2020. Region 9 had the highest, upward change in slaughter, with 2020 rates increasing 12 percent from 2019 levels.

Table 2

Total slaughter in 2019 and 2020 by region

Region	Total slaughter (2019)	Total slaughter (2020)	Percent change (percent)	Share of total slaughter in 2020 (percent)
Region 1	29,800	32,000	7.4	0.0
Region 2	127,500	97,000	-23.9	0.1
Region 3	5,811,000	5,608,000	-3.5	4.3
Region 4 and 8	21,511,500	20,307,100	-5.6	15.5
Region 5	37,044,000	38,542,200	4.0	29.5
Region 6	5,961,500	6,127,200	2.8	4.7
Region 7	56,032,700	57,090,400	1.9	43.7
Region 9	2,374,300	2,662,800	12.2	2.0
Region 10	348,200	347,500	-0.2	0.3

Note: States included in regions are as follows: Region 1—Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont; Region 2—New Jersey and New York; Region 3—Delaware, Maryland, Pennsylvania, Virginia, and West Virginia; Region 4—Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee; Region 5—Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin; Region 6—Arkansas, Louisiana, New Mexico, Oklahoma, and Texas; Region 7—Iowa, Kansas, Missouri, and Nebraska; Region 8—Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming; Region 9—Arizona, California, Hawaii, and Nevada; Region 10—Alaska, Idaho, Oregon, and Washington.

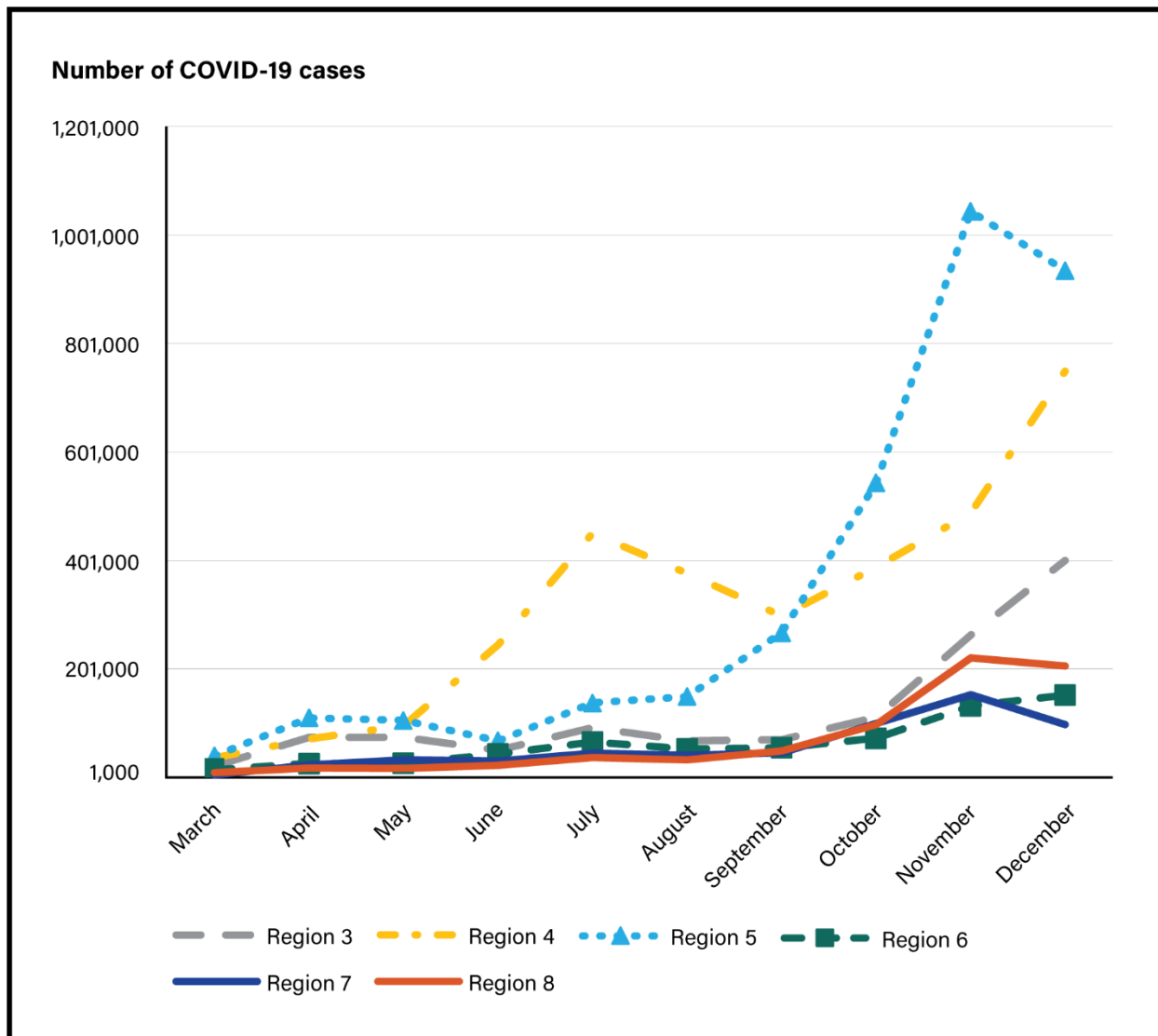
Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Quick Stats 2019 and 2020 slaughter of hogs, measured in head.

Slaughter data for Regions 4 and 8 are withheld to avoid disclosing data for individual operations. To calculate slaughter volumes in both regions (combined), we subtract the total sum of slaughter in all available regions from U.S. total slaughter numbers. Thus, we have partial information on the aggregate changes in the two regions combined, which we report in the statistics in Appendix C.

The Centers for Disease Control and Prevention provides data on daily reported COVID-19 cases. Figure 3 summarizes the monthly COVID-19 cases in 2020 in the major pork processing regions.⁶ Regions 4 and 5 experienced the highest number of COVID-19 cases since the beginning of the pandemic, followed by Region 3 (CDC, 2021a). For Region 5, cases were on the rise starting in July and peaked in November, reaching more than 1 million cases. In Region 4, new cases increased strongly in June, dropped in August and September, and resumed their upward trajectory in October.

⁶ We summarize COVID-19 cases for other regions in Appendix A, Figure A1.

Figure 3
Number of COVID-19 cases reported in 2020 by region level



Source: USDA, Economic Research Service using data from the Centers for Disease Control and Prevention on COVID-19 cases by county, aggregated to region level.

The incidence of COVID-19 varied across regions, and so did its relation to regional hog slaughter rates. Table 3 provides correlation coefficients between regional slaughter and COVID-19 cases. We report the correlation for the first 23 weeks of 2020 (January 1–June 7) and the entire year. During the first months of the pandemic, cases had a high degree of negative correlation with slaughter in most regions, including Regions 5 and 7, the two major pork processing regions. This suggests that as COVID-19 cases increased, slaughter rates decreased in most of the regions. However, when looking at slaughter and reported cases for the entire year, we see the relationship between these two variables weaken. In fact, Table 3 suggests that in many regions, considering the entire year, slaughter increased as COVID-19 cases also increased. Jointly these correlation coefficients suggest that hog slaughter was primarily affected at the start of the pandemic, but as cases continued to increase (primarily in larger cities within a region), slaughter rates also improved for most of the regions as the industry adapted to the pandemic.

We conjecture the change in correlation between cases and slaughter volumes from the initial 24 weeks in 2020 has to do with the pork packing industry being located outside major metropolitan areas and the extensive steps the industry took to limit infections. Since most medium and large plants are located in rural, nonmetro areas and the increases in COVID-19 cases were concentrated in larger metro areas, there is almost no relationship between the incidence of COVID-19 and slaughter volumes after the first few months of the pandemic. Early in the pandemic, the spread of COVID-19 happened in outbreak clusters where one environment was the source of spread (indoor, high number of people inside, low ventilation). Meatpacking plants, especially pork and beef, were hotbeds for the spread of COVID-19. Shortly after the start of the pandemic, the industry took steps to reduce infection rates and, as the virus continued to spread throughout the U.S., daily infections increased because of community spread, not isolated outbreak clusters (Saitone et al., 2021).

Table 3

Correlation between regional slaughter rates and COVID-19 reported cases, 2020

Region	Correlation (first 24 weeks in 2020)	Correlation (all year)
Region 1	0.30	0.14
Region 2	-0.78	-0.28
Region 3	-0.43	-0.26
Region 4 and 8	-0.68	0.04
Region 5	-0.64	0.17
Region 6	-0.31	0.09
Region 7	-0.79	0.06
Region 9	-0.29	0.04
Region 10	0.13	-0.08

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Quick Stats and the Centers for Disease Control and Prevention.

Lastly, we rely on a listing of 74 major pork packing plants that account for 95 percent of hog slaughter in the United States (Meyer 2020). We use this listing and the estimated plant capacities to identify the distribution of plant sizes across the NASS slaughter regions. Depending on daily estimated slaughter capacity, we classify plants into three categories:

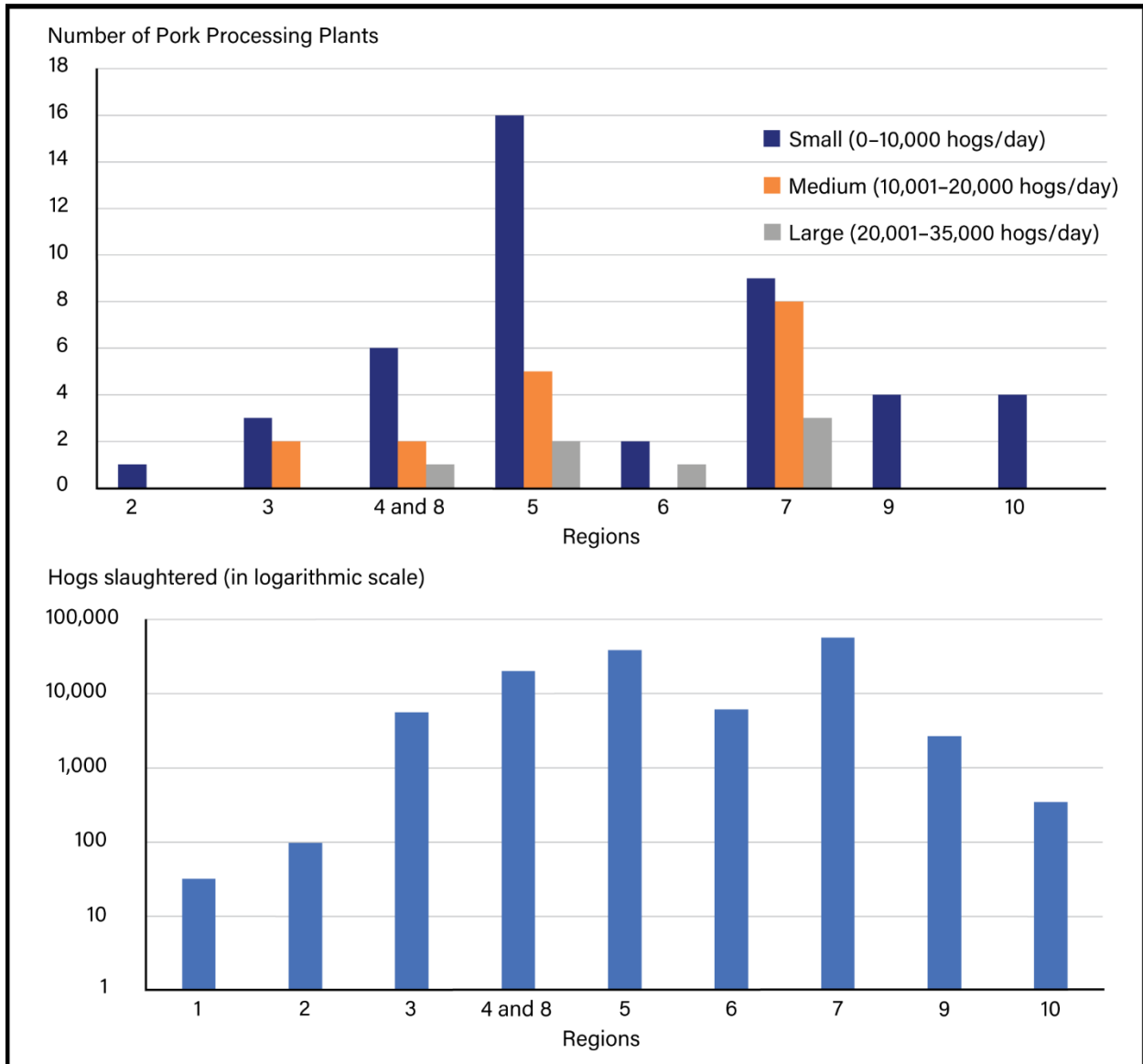
- Small plants have an estimated slaughter capacity up to 10,000 hogs per day;
- Medium plants have an estimated capacity between 10,001–20,000 hogs per day, and
- Large facilities have an estimated capacity of more than 20,000 hogs per day.

Region 7 has more large and medium plants compared to the rest of the regions (figure 4a), followed by Region 5. As expected, Region 7 has the highest slaughter volume in 2020, with Region 5 having the

second highest, and followed by Regions 4 and 8 combined (figure 4b). This suggests regions with larger plants slaughter more hogs than those regions with smaller plants.

Figures 4a and 4b

Number of pork processing plants and hogs slaughtered by region, 2020



Notes: Values in y-axis in figure 4b are displayed in a logarithmic (log) scale. States included in regions are as follows: Region 1—Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont; Region 2—New Jersey and New York; Region 3—Delaware, Maryland, Pennsylvania, Virginia, and West Virginia; Region 4—Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee; Region 5—Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin; Region 6—Arkansas, Louisiana, New Mexico, Oklahoma, and Texas; Region 7—Iowa, Kansas, Missouri, and Nebraska; Region 8—Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming; Region 9—Arizona, California, Hawaii, and Nevada; Region 10—Alaska, Idaho, Oregon, and Washington.

Source: USDA, Economic Research Service using data from Meyer (2020) for figure 4a and data from USDA, National Agricultural Statistics Service Quick Stats for figure 4b.

Changes in Regional Slaughter Rates in 2020

Much discussion related to pork packing plants in 2020 has centered on plant-specific closures, re-openings, slowdown announcements, and slaughter volumes (Balagtas and Cooper, 2021; Cowley, 2020; Muth and Read, 2020; Tonsor and Schulz, 2020b). However, the pandemic did not equally affect each U.S. region. Here, we measure year-to-year changes in slaughter rates by region. First, we discuss slaughter changes in major pork processing regions with the start of the pandemic, followed by changes in regions with less processing capacity.

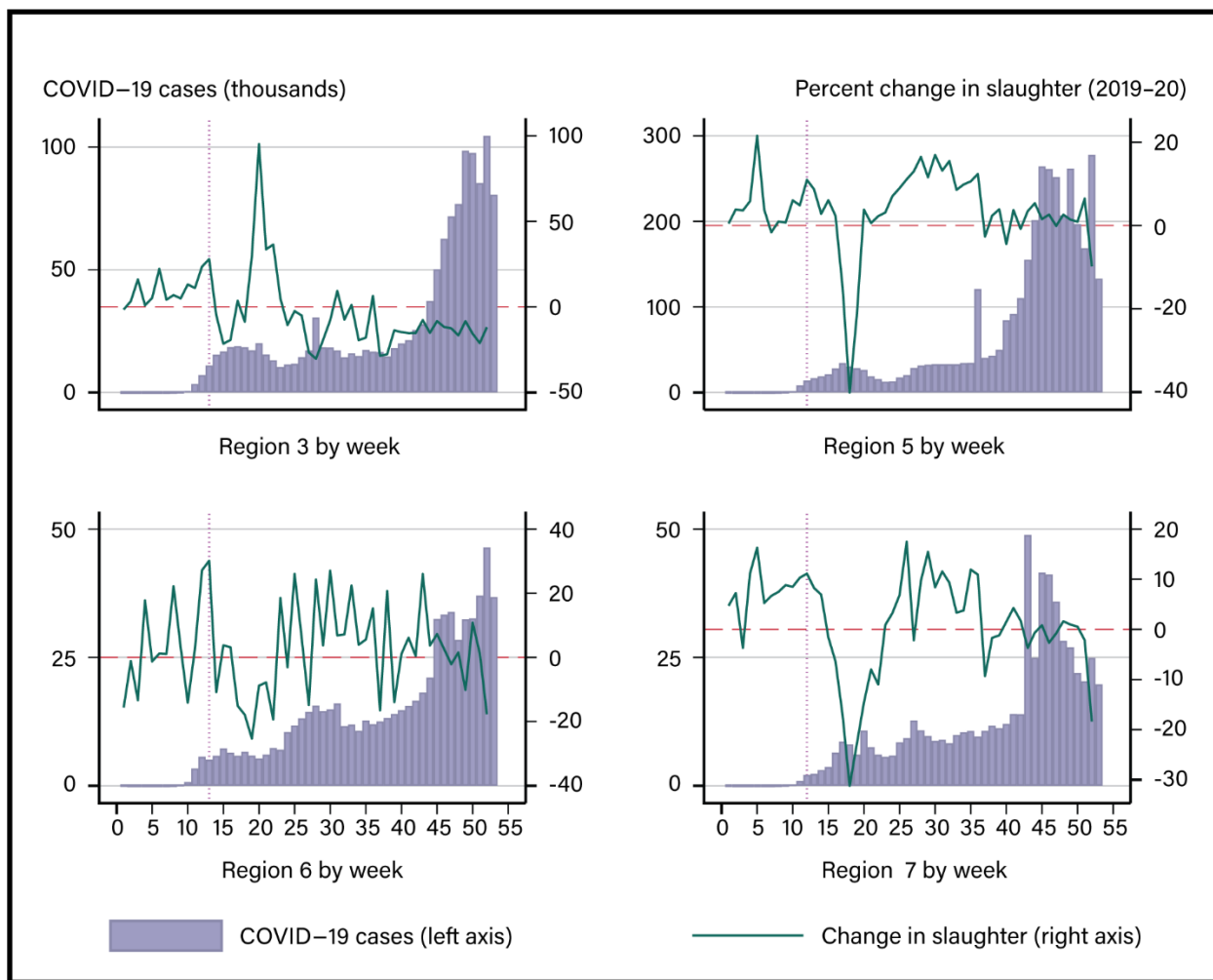
Major Pork-Producing Regions—3, 5, 6, 7

The onset of the pandemic negatively affected major pork processing regions. Because of the relative importance of these regions to the sector, the entire supply chain was disrupted as slaughter rates plummeted. However, the negative impact from COVID-19 was short-lived among most major pork-processing regions.⁷

Figure 5 displays weekly COVID-19 cases and slaughter rates for each major pork-processing region. We include Regions 3, 5, 6, and 7 as major processing regions; of these, Regions 5 and 7 are the largest. We highlight the week of March 23, 2020, because that is when the United States began to lead the world in confirmed cases (Taylor, 2021) and stay-at-home orders and restrictions were imposed by many States. Regions 3, 5, 6, and 7 experienced lower slaughter rates for approximately 5 to 7 weeks between April–June 2020, and then slaughter rates rebounded to levels close to 2019 for some regions. In the beginning of the pandemic, slaughter volumes in the major pork processing regions, Regions 5 and 7, were more drastically affected than rates in Regions 3 and 6. Slaughter rates in Region 5 decreased 40 percent compared to 2019 in the first week of May, while rates in Regions 3, 6, and 7 decreased 8 percent, 18 percent, and 31 percent, respectively (figure 5). However, the trajectory of recovery and trends in 2020 slaughter rates compared with 2019 differed across these regions.

⁷ Although Regions 4 and 8 are important regions for pork processing, we discuss these regions in the appendix. USDA, National Agricultural Statistics Service does not release regional, weekly slaughter rates for these regions separately, so we are not able to disentangle the effects of COVID-19 and fully capture the recovery trajectory of these region separately.

Percent changes in hog slaughter rates for major U.S. pork processing regions



Notes: The vertical line highlights week 13, the week when the U.S led the world in confirmed cases (Taylor, 2021). States included in regions are: 3—Delaware, Maryland, Pennsylvania, Virginia, West Virginia; 5—Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin; 6—Arkansas, Louisiana, New Mexico, Oklahoma, Texas; 7—Iowa, Kansas, Missouri, Nebraska.

Source: USDA, National Agricultural Statistics Service Quick Stats, Centers for Disease Control and Prevention reported COVID-19 cases.

For the rest of 2020, slaughter rates in Region 3 fluctuated more, with more frequent, one-week sharp declines in slaughter volumes compared to 2019. It was not until the week of September 7 that the 2020 slaughter rates started to follow a similar trend to rates in 2019. However, the 2020 rates were lower than in 2019 for most of the year, suggesting the region did not recover as much as other major processing regions. The total slaughter count in 2020 declined by 2 percent compared with 2019. While Region 3 had the 5th-highest slaughter count, it remained far behind the top-3 pork processing regions.

Region 5 has some of the largest pork packing plants and the most major plants in the United States. This region experienced the second highest number of COVID-19 cases at the beginning of the pandemic (CDC, 2021a). Some of the major pork packing plants in the region temporarily shut down (e.g., JBS

USA in Worthington, MN; Smithfield Foods in Monmouth, IL; and Tyson Foods in Logansport, IN),⁸ which largely explains the declines in slaughter during April and May 2020. Specifically, total slaughter went from 815,100 head per week for the week ending on March 21 to 399,000 head per week in the last week of April. Beginning in May, slaughter rates rebounded and eventually exceeded slaughter rates in 2019 (table

A significant decline in slaughter in Region 5 would be expected to disrupt the industry considerably. Production changes from the concentrated medium and large pork processing plants in this region has the potential to affect the market. Nonetheless, we observe the resiliency of the plants in Region 5 after the start of the pandemic, when slaughter recovered and surpassed 2019 levels by June 2020. The number of hogs slaughtered in 2020 exceeded the number of hogs slaughtered 2019 by 5 percent. Looking at rates disaggregated by week, slaughter volumes in Region 5 fully recovered (table B1) with most of the weeks having positive percent change in slaughter counts compared with 2019.

At the beginning of the pandemic, slaughter rates in Region 6 declined from a high of 140,000 head in Week 13 to 80,000 in Week 14. During the next two weeks, the slaughter volumes in the region increased to 100,000 head per week, and then decreased the following week to 90,000 head per week (table B1).

Similarly, Region 7 also experienced a deep decline in slaughter rates starting the week of March 15, with rates declining by 42 percent in early May (Figure 6). However, by the week of June 1 slaughter rates in 2020 surpassed those in 2019. This trend continued until the beginning of September when 2020 rates declined briefly but followed a similar trend to rates in 2019. For the remainder of the year, rates were on par with 2019 slaughter.

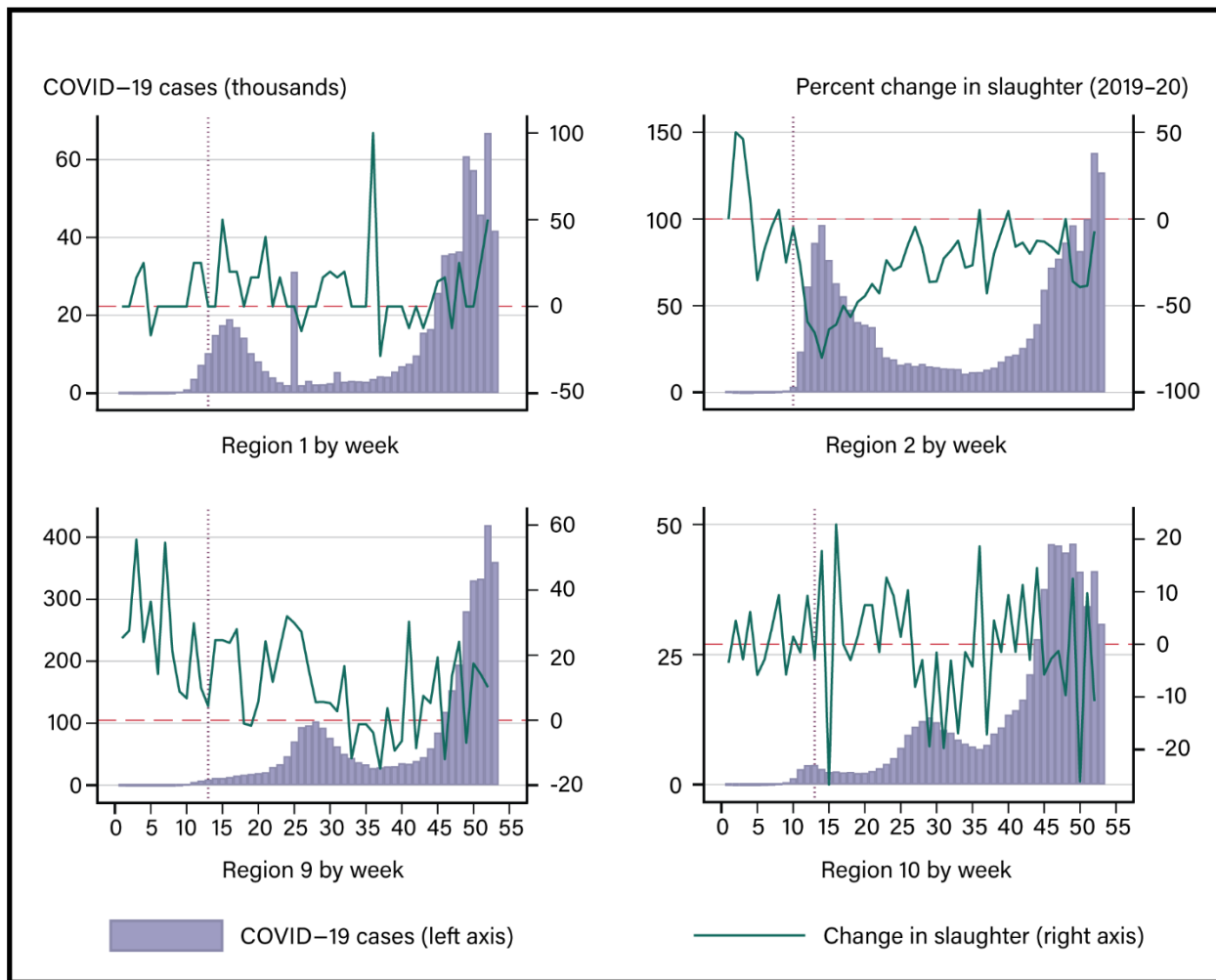
Other Regions—1, 2, 9, and 10

COVID-19 also affected other U.S. regions that do not have many medium and large processing plants, but the change in slaughter varied across regions.

Region 1, which includes northeastern States, did not see its slaughter rates seriously affected by the pandemic. As cases increased in the beginning of the COVID-19 pandemic, the number of hogs slaughtered in 2020 increased compared with 2019 (figure 6). As cases continued to rise, slaughter rates followed the 2019 rates with some upward jumps in rates in 2020. Region 1 does not have any major pork processing plants, and total slaughter counts are the lowest compared to the other regions. Production in Region 1 comprises 0.02 percent of the total number of hogs slaughtered in 2020 (table 2). Any changes in slaughter resulting from a negative shock, such as COVID-19, would not severely affect the industry.

⁸ The JBS USA closure was reported by several news outlets. Smithfield and Tyson both released statements stating the reason and time of closure.

Percent changes in hog slaughter rates for Regions 1, 2, 9 and 10



Notes: The vertical line highlights week 13, the week when the U.S led the world in confirmed cases (Taylor, 2021). States that comprise regions are: 1—Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; 2—New Jersey, New York; 9—Arizona, California, Hawaii, Nevada; 10—Alaska, Idaho, Oregon, Washington.

Source: USDA, National Agricultural Statistics Service Quick Stats, Centers for Disease Control reported COVID-19 cases.

Compared to Region 1, COVID-19 severely hindered pork processing in Region 2. From the week of March 23, Region 2 (which comprises New Jersey and New York) had the largest percentage decline in slaughter rates compared to other regions over the same period. This period of decline in processed pork corresponds to the fast rise in COVID-19 cases in New York and the start of the pandemic restrictions there.⁹ On average, 56 percent fewer hogs were slaughtered in Region 2 between March and May 2020 compared with the same period in 2019, with the largest percent difference (-80 percent) happening the week of March 29, 2020 (figure 6). Region 2 did not recover to slaughter rates above or equal to those in

⁹ New York Governor Andrew Cuomo declared a state of emergency on March 7. By March 20, the State was on full lockdown (Cuomo, 2020).

2019 for the rest of the year,¹⁰ though the difference between 2019 and 2020 slaughter was never as large again as it was between April and June. Since the start of the COVID-19 restrictions in New York, only 3 weeks out of the remaining 42 had higher slaughter volumes in 2020 compared with 2019 (table B1). Similarly, the total number of hogs slaughtered in Region 2 in 2020 was 22 percent less than compared with 2019 (table 2).

Region 2 also ranked highest in number of COVID-19 cases over the same period. Early in the pandemic, New York was the epicenter of new cases in the United States, and restrictions there were among the strictest in the country. Although cases were higher at the end of the year than they were in the spring, the 2020 slaughter volume relative to 2019 did not fall as much as it did in the spring.

The relative importance of pork processing is necessary when evaluating the effect of COVID-19 within and across regions. The pandemic affected Region 2 the most, in terms of percent changes in slaughtering between 2019 and 2020. However, Region 2 does not process as many hogs as other regions and does not have any plants that slaughter more than 10,000 hogs a day. It had the second smallest total slaughter count in both 2019 and 2020 (table 2). Since slaughter counts in Region 2 are minor compared to other regions, changes in slaughter volumes within Region 2 have a small effect on the sector's overall resilience.

Slaughter rates of Region 9 were less affected by the pandemic than other regions (figure 6). Region 9 experienced a small decline in slaughter during the week of August 15, but it did not correspond with a rise in COVID-19 cases. The number of hogs slaughtered in 2020 in Region 9 increased by 14 percent compared with the slaughter count in 2019.

Finally, Region 10 experienced a single decline in slaughter volumes during the week of April 4, 2020. Rates shortly increased, then declined in the beginning of July, only to follow an upward trend until the end of October. Overall, total slaughter increased by 1 percent in Region 10 in 2020 compared with 2019.

¹⁰ This could be the result of State and local restrictions. For example, the New York State emergency declaration expired on June 24, 2021, well over a year since it was first announced. However, we cannot be certain why the decline in slaughter lasted so long in this region without plant-level analysis, which is beyond the scope of this report.

Conclusion

Slaughter rates across regions in the United States were reduced by plant slowdowns and closures because of the COVID-19 pandemic. However, the magnitude and persistence of shocks from COVID-19 to pork producers varied by region. In this report, we explored the heterogeneity in regional slaughter rates and describe the effect of the pandemic using year-to-year comparisons. This report's regional analysis indicates that COVID-19 had a detrimental effect on regional slaughter volumes in the beginning months of the pandemic, but each region recovered differently.

Major pork processing regions, such as Regions 5 and 7, had between 30–40 percent declines in weekly slaughter volumes compared with 2019, but these declines occurred for approximately three weeks at the start of the pandemic (table B1). Both regions were temporarily affected and recovered even as cases in the area continued to increase for the rest of 2020. The changes in slaughter rates in these two regions are the main drivers of the aggregate change in slaughter rates between 2019 and 2020, as jointly these regions make up 73 percent of total pork processed in the United States. Region 2 experienced a more persistent effect, as slaughter rates in 2020 did not completely recover to 2019 levels. We conjecture the large percentage changes in slaughter volume in Region 2 did not have a significant effect on the packing sector because total slaughter volume in Region 2 is less than 1 percent of total U.S. volume.

The decline in processing affected the entire pork supply chain. At the farm, disruptions to processing resulted in higher variable costs and disturbances to the pipeline hog supplies, as hogs have scheduled slaughter times to coincide with when they are finished (when they reach slaughter weight). Therefore, exploring in-depth the effect of the pandemic across regions is beneficial, as the resiliency of packing plants and regions affects the proper functioning of the entire supply chain.

Overall, we find an indication that pork processors in most regions were able to overcome some of the disruptions resulting from the COVID-19 pandemic. Regions with larger plants were able to recuperate shortly (1–2 month) after the start of the pandemic. Regions with smaller hog operations on average experienced mixed recovery trajectories. This relationship may have implications for the future of the industry if plants in those regions have long-term problems recovering from the COVID-19 crisis. This report alludes to how the location of plants across different regions might be related to the magnitude of the effect of COVID-19 on slaughter and the recovery from the initial COVID-19 shock. We find interesting correlations between COVID-19 cases and regional slaughter volumes, confirming a heterogeneous effect of the pandemic on regional slaughters.

However, we are not able to determine causal effects or other determinants of resiliency. Our results provide evidence that, on a regional level, having larger plants did not lead to greater disruptions to slaughter rates. But we are not able to determine the causal effect of plant size on the likelihood of shutting down, as regions vary in other ways that could affect the pork packing industry's resilience to shocks. Plant-level analysis may be required to fully understand the effects of plant characteristics and industry structure on the resilience and recovery of the sector.

References

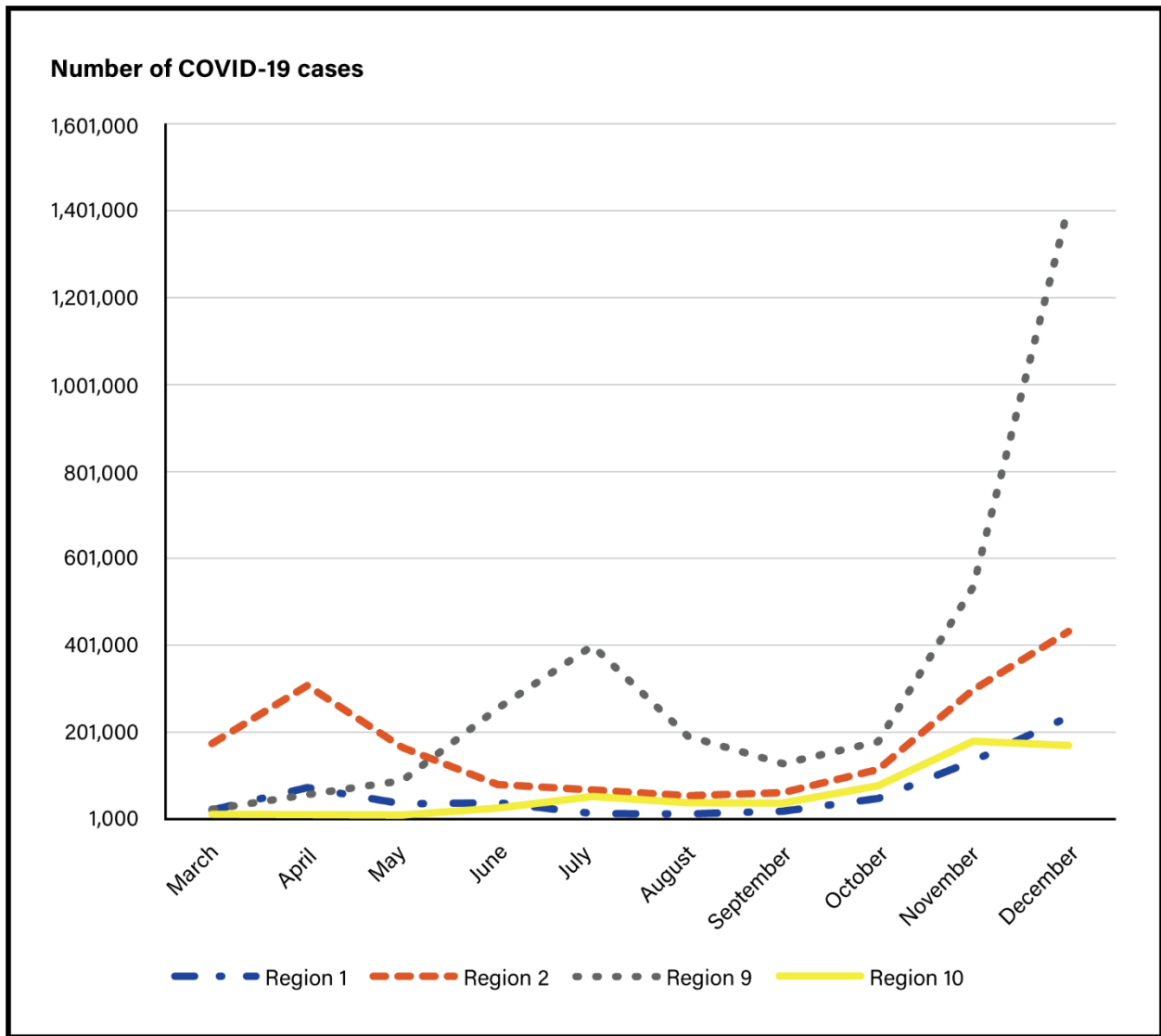
- Aufrichtig, A., L. Buchanan, M. Corkery, and Y. Parshina-Kottas. June 8, 2020. “Take a Look at How COVID-19 is Changing Meatpacking Plants,” *The New York Times*.
- Balagtas, J. V., and J. Cooper, J. 2021. “The Impact of COVID-19 on United States Meat and Livestock Markets,” *Choices* 36(3):10.
- Broadway, M. J., and T. Ward. 1990. “Recent changes in the structure and location of the US meatpacking industry,” *Geography* 75(1):7679. JSTOR.
- Centers for Disease Control and Prevention (CDC). 2021a. “COVID-19 Case Surveillance Restricted Use Data.”
- Centers for Disease Control and Prevention (CDC). February 2021b. “Meat and Poultry Processors: Interim Guidance from CDC and the Occupational Safety and Health Administration (OSHA).”
- Cowley, C. July 2020. *COVID-19 Disruptions in the U.S. Meat Supply Chain*, Federal Reserve Bank of Kansas City.
- Cuomo, A. 2020. *Declaring a Disaster Emergency in the State of New York*. New York State.
- Haley, M. M. 2004. *Market Integration in the North American Hog Industries*, Electronic Outlook Report LDP-M-125-01, U.S. Department of Agriculture, Economic Research Service.
- Hart, C., J. Crespi, D.J Hayes, K.L. Jacobs, and L.L. Schulz. 2020. “*The Impact of COVID-19 on Iowa’s Corn, Soybean, Ethanol, Pork, and Beef Sectors*,” CARD Policy Briefs No. 20-PB 28; CARD Reports and Working Papers, Iowa State University.
- Hayes, D. J., C.E. Hart, K.L. Jacobs, and L.L. Schulz. 2021. “A descriptive analysis of the COVID-19 impacts on U.S. pork, turkey, and egg markets,” *Agribusiness* 37(1):122141.
- Ishmael, W. January 2017. “Is Packing Capacity Keeping Up with Full Throttle Cowherd Expansion?” *Beef Magazine*.
- Lusk, J. October 2020. “Size and Vulnerability in Meat Packing.” *Jayson Lusk, Food and Agricultural Economist*.
- Lusk, J., L.L. Schultz, and Tonsor, G. T. 2021. “Beef and Pork Marketing Margins and Price Spreads during COVID-19,” *Applied Economic Perspectives and Policy* 43(1):423.
- MacDonald, J. M., and M.E. Ollinger, M. E. 2000. “Scale Economies and Consolidation in Hog Slaughter,” *American Journal of Agricultural Economics* 82(2):334–346.
- MacDonald, J. M., C.R. Handy, K.E. Nelson, and M.E. Ollinger. 2000). *Consolidation in U.S. Meatpacking*, U.S. Department of Agriculture, Economic Research Service.
- Meyer, S. 2020. “Pork Packing: Just What is Capacity?” Pork Capacity Report 2020. *National Hog Farmer*.
- Muth, M., and Q. Read, Q. July 2020. “Effects of COVID-19 Meat and Poultry Plant Closures on the Environment and Food Security.” *Insights Blog*.
- Nalivka, J., 2020. “The Economics of Capacity and Utilization [Pork Business],” *Farm Journal—Pork*.
- National Pork Producers Council. 2020. *The Tragic Impact of COVID-19 on U.S Hog Farmers: The Need to Euthanize*. Fact Sheet.
- Pellegrini, M., 2020. “The State of the Workforce 2020: COVID-19 Catalyzes a Reckoning (State of the Industry 2020),” *The National Provisioner*.
- Pitt, D., July 2021. “USDA Unveils Plan to Help Build Small Meat Processing Plants,” *Associated Press*.
- Polansek, T., and A. Sullivan. June 2020. “Meatpacking workers often absent after Trump order to reopen,” *Reuters*.

- Ramsey, A. F., B.K. Goodwin, W.F. Hahn, and M.T. Holt. 2021. "Impacts of COVID-19 and Price Transmission in U.S. Meat Markets," *Agricultural Economics*, 52(3):441458.
- Saitone, T. L., K. Aleks Schaefer, and D.P. Scheitrum. 2021. "COVID-19 morbidity and mortality in U.S. meatpacking counties." *Food Policy*, 101, 102072.
- Schulz, L., 2020. "Hog Producers Limited in Short-run to Change Production," *Ag Decision Maker*, 24(6).
- Taylor, D. B. March 17, 2021. "A Timeline of the Coronavirus Pandemic," *The New York Times*.
- Tonsor, G. T., and L. Schulz 2020a. "Assessing Impact of Packing Plant Utilization on Livestock Prices." Extension Publication. Kansas State University, Manhattan, KS.
- Tonsor, G. T., and L. Schulz. 2020b. "COVID-19 Impacts on the Meat Processing Sector. In *Economic Impacts of COVID-19 on Food and Agricultural Markets*." Council for Agricultural Science and Technology (CAST).
- U.S. Department of Agriculture, National Agricultural Statistics Service. 2020a. *Livestock Slaughter 2019 Summary*.
- U.S. Department of Agriculture, National Agricultural Statistics Service. 2020b. *Quick Stats Database*.
- U.S. Department of Agriculture, National Agricultural Statistics Service. 2021. *Livestock Slaughter 2020 Summary*.
- U.S. Department of Agriculture, Office of the Chief Economist. 2020. *World Agricultural Supply and Demand Estimates (WASDE)*.
- Weersink, A., N. Bannon, N., J. Ifft, J. Maples, K. McEwan, M.G.S. McKendree, C. Nicholson, A. Novakovic, A. Rangarajan, T. Richards, B. Rickard, J. Rude, M. Schipanski, G. Schnitkey, L. Schulz, D. Schuurman, K. Schwartzkopf-Genswein, M. Stephenson, M. von Massow, and K. Wood. 2021. "COVID-19 and the agri-food system in the United States and Canada," *Agricultural Systems*, 188, 103039.

Appendix

Appendix A

Figure A1
COVID-19 cases in regions without major pork packing plants, 2020



Source: USDA, Economic Research Service using data from the Centers for Disease Control and Prevention on COVID-19 cases by county, aggregated to region level.

Appendix B

Table B1

Percent changes in weekly slaughter rates by region (2019 –20)

Week	Regions									
	1	2	3	4 & 8	5	6	7	9	10	
1	0.00	0.00	-1.50	1.01	0.48	-15.62	4.72	25.25	-3.51	
2	0.00	50.00	3.34	3.53	3.87	-1.12	7.24	27.55	4.48	
3	16.67	46.15	16.12	0.07	3.62	-13.35	-3.67	55.52	-2.86	
4	25.00	11.76	0.96	6.33	5.84	17.80	11.15	24.09	6.15	
5	-16.67	-35.29	5.25	1.41	21.55	-1.24	16.27	36.49	-5.80	
6	0.00	-17.39	22.26	10.26	3.82	1.21	5.27	14.19	-2.90	
7	0.00	-4.55	4.23	2.10	-1.63	1.09	6.69	54.60	2.94	
8	0.00	5.26	6.95	-0.89	0.96	22.20	7.48	21.29	9.38	
9	0.00	-25.00	4.99	3.92	0.71	3.19	8.82	8.84	-5.71	
10	0.00	-5.00	13.17	4.25	6.07	-14.11	8.50	6.77	1.47	
11	25.00	-26.92	11.09	4.48	4.86	2.54	10.30	29.80	-1.52	
12	25.00	-59.26	23.59	8.66	10.97	27.20	11.12	10.02	9.23	
13	0.00	-65.52	27.93	7.95	8.70	30.12	8.26	4.36	-2.74	
14	0.00	-80.00	-4.70	6.51	2.81	-10.79	6.93	24.62	17.74	
15	50.00	-63.64	-21.49	-2.67	6.09	3.77	-1.59	24.62	-26.67	
16	20.00	-60.87	-19.27	-22.06	2.35	3.17	-6.36	23.81	22.81	
17	20.00	-50.00	3.63	-20.85	-14.79	-15.07	-17.07	27.98	0.00	
18	0.00	-56.52	-8.61	-51.94	-40.11	-17.86	-31.18	-1.02	-2.99	
19	16.67	-47.83	29.68	-38.42	-21.63	-25.28	-22.88	-1.71	1.49	
20	16.67	-44.44	95.21	-33.58	3.82	-8.80	-14.57	5.66	7.46	
21	40.00	-37.50	33.68	-22.79	0.59	-7.78	-8.00	24.26	7.46	
22	0.00	-42.86	36.45	-20.37	2.24	-19.33	-10.97	11.81	-1.47	
23	16.67	-23.81	5.03	-5.81	3.12	18.55	0.88	22.05	12.70	
24	0.00	-29.63	-10.58	-12.96	7.05	-3.06	3.25	31.96	9.23	
25	0.00	-27.27	-2.42	-7.64	8.98	26.03	6.83	29.93	1.45	
26	-14.29	-14.81	-5.00	-5.31	11.09	5.98	17.48	27.20	10.29	
27	0.00	-4.55	-26.59	-9.83	13.00	-14.84	-2.16	15.83	-8.06	

28	0.00	-16.67	-30.23	-7.18	16.47	24.28	9.67	5.54	-2.99
29	16.67	-36.36	-19.24	4.11	11.59	3.78	15.45	5.61	-19.40
30	20.00	-36.00	-7.74	-1.03	16.95	27.03	8.40	5.29	-1.56
31	16.67	-22.73	9.39	-8.56	13.20	6.87	11.54	2.74	-19.72
32	20.00	-18.18	-7.31	1.62	15.49	7.16	9.29	16.63	-3.08
33	0.00	-12.50	1.18	-10.66	8.57	22.40	3.34	-11.72	-16.90
34	0.00	-28.00	-19.43	-0.07	9.86	3.97	3.76	-1.22	-1.49
35	0.00	-26.67	-17.91	-0.37	10.61	5.57	11.93	-1.20	-4.23
36	100.00	5.26	6.45	9.90	12.40	15.27	10.91	-3.77	18.64
37	-28.57	-42.86	-28.58	-21.96	-2.65	-16.49	-9.31	-14.86	-17.14
38	0.00	-20.00	-27.61	-1.32	2.37	20.71	-1.68	3.68	4.55
39	0.00	-7.69	-13.64	-2.19	3.91	-13.94	-1.18	-9.36	-1.43
40	0.00	4.55	-14.73	-2.43	-4.43	1.06	1.52	-6.41	9.38
41	-12.50	-16.00	-15.28	-9.20	3.70	6.15	4.26	30.27	-1.41
42	0.00	-13.64	-15.26	-6.60	-0.80	0.46	1.75	-8.57	11.29
43	-12.50	-20.00	-7.63	-4.29	3.46	26.01	-3.70	7.49	-2.94
44	0.00	-12.50	-15.11	-1.19	5.36	3.73	-0.64	5.31	14.52
45	14.29	-13.04	-8.26	-6.36	1.55	7.26	0.82	19.32	-5.71
46	16.67	-16.00	-11.71	-11.18	2.62	2.56	-2.65	-11.96	-2.70
47	-12.50	-20.00	-12.50	-4.06	-0.09	-2.11	-0.79	13.63	-1.25
48	25.00	0.00	-16.60	-3.30	2.62	1.56	1.62	24.13	-9.68
49	0.00	-36.00	-8.33	-2.78	1.41	-10.11	0.96	-6.90	12.50
50	0.00	-39.29	-15.62	-6.15	0.93	10.82	0.54	17.43	-26.09
51	25.00	-38.46	-21.09	-6.04	6.48	1.28	-2.17	14.15	9.72
52	50.00	-7.14	-11.86	-16.65	-9.80	-17.68	-18.35	10.18	-10.77
								0.13	-0.08

Note: States included in regions are as follows: Region 1—Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont; Region 2—New Jersey and New York; Region 3—Delaware, Maryland, Pennsylvania, Virginia, and West Virginia; Region 4—Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee; Region 5—Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin; Region 6—Arkansas, Louisiana, New Mexico, Oklahoma, and Texas; Region 7—Iowa, Kansas, Missouri, and Nebraska; Region 8 - Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming; Region 9—Arizona, California, Hawaii, and Nevada; Region 10—Alaska, Idaho, Oregon, and Washington.

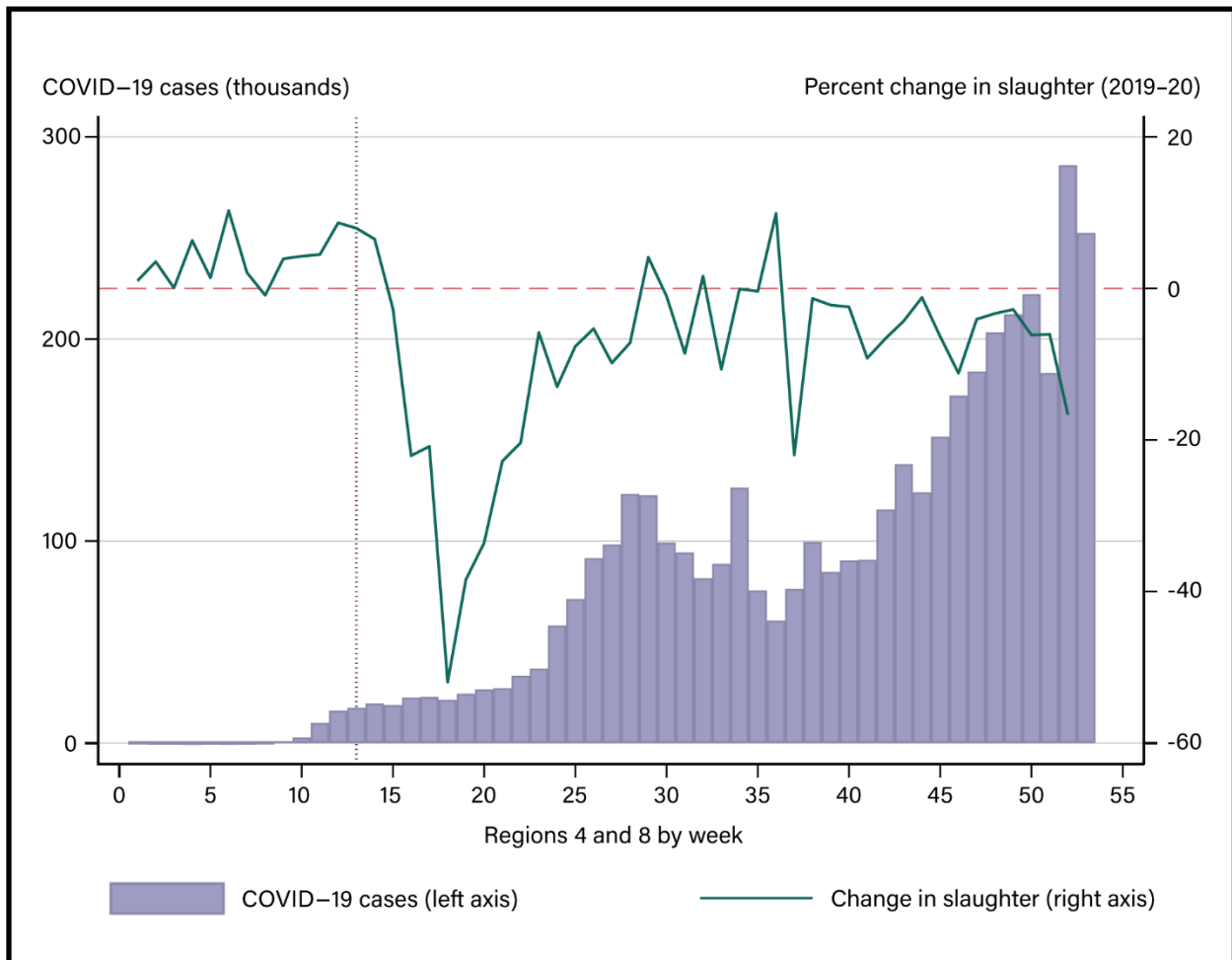
Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Quick Stats.

Appendix C

Total slaughter volumes were 4 percent lower in 2020 than 2019 in Regions 4 and 8 (table 2). These regions are important for pork processing as some of the largest pork packing plants are in these two regions. For example, the Smithfield plant in Tar Heel, NC (Region 4) has an estimated daily slaughter capacity of 34,500 hogs, making it the largest U.S. plant (Meyer, 2020). The Smithfield plant in Sioux Falls, SD (Region 8) is also among the largest with slaughtering capacity estimated at 19,500 hogs per day. Disruptions to both plants affected the regional slaughter volumes and the entire pork industry.

In Regions 4 and 8, cases of COVID-19 remained relatively low in the spring when slaughter rates fell the most. The cases began to increase in June and by that time, slaughter had begun to recover (figure C1). The weeks of July 6 and July 19 had higher case counts in Regions 4 and 8, but slaughter estimates during those weeks were only marginally less compared to the respective weeks in 2019 (table B1). This speaks to some resiliency of packing plants in the region, although slaughter rates were somewhat lower in 2020.

Figure C1
Change in slaughter rates, 2019–20



Note: States included in regions 4 and 8 include: Region 4—Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee; Region 8—Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.

Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service Quick Stats and the Centers for Disease Control and Prevention.