U.S. DEPARTMENT OF AGRICULTURE
Economic Research Service

COVID-19 Working Paper #AP-092

September 2021

COVID-19 Working Paper: Meatpacking Working Conditions and the Spread of COVID-19

Thomas P. Krumel, Jr. and Corey Goodrich

Abstract

This preliminary analysis explores how working conditions in meatpacking plants might have contributed to the spread of the Coronavirus (COVID-19). Data from the Occupational Information Network (O*NET) was used to construct a set of industry-level working condition variables and compare meatpacking to the sample of other manufacturing industries in our comparison group. This novel approach showed that proximity to others in the meatpacking industry is likely the main factor that influenced the spread of COVID-19, nearly three standard deviations higher in meatpacking than our comparison sample of other manufacturing industries. Overall exposure to disease was also found to be 2.5 standard deviations higher in the meatpacking industry compared to other manufacturing industries. Subsequently, we performed a county-level analysis on COVID-19 spread, comparing rural counties that have a large number of meatpacking plants to other nonmetropolitan counties that were dependent on a single manufacturing industry, using the time frame of mid-March to mid-September of 2020. Data analysis begins in mid-March since confirmed cases became national in scope at this point. In mid-April 2020, COVID-19 cases in meatpacking-dependent rural counties rose to nearly 10 times the number in comparison to rural counties dependent on other single manufacturing industries. This difference disappears completely by mid-July, driven by a reduction in COVID-19 cases in the meatpacking industry rather than an increase in other industries, and holds steady through mid-September. The paper concludes by collating evidence from other studies to infer that the meatpacking industry's increased precautions to protect workers help explain why no difference was observed between meatpacking-dependent counties and our comparison group for the final 2 months of the study period. However, this inference should be viewed as suggestive since it cannot formally test using the data referenced in the working paper.

Keywords: COVID-19, epidemic, meatpacking industry, rural communities, working conditions.

About the Authors

Thomas P. Krumel, Jr., an assistant professor of agribusiness and applied economics at North Dakota State University, completed this report while working as a research agricultural economist with USDA, Economic Research Service. Corey Goodrich is a research analyst, University of Connecticut, Department of Agricultural and Resource Economics.

Table of Contents

Meatpacking Working Conditions and the Spread of COVID-19

Summary

What Is the Issue?

This working paper aims to empirically identify the likely mechanism that led to widespread outbreaks of the Coronavirus (COVID-19) virus within the meatpacking industry—the physical proximity of workers. While the media and other researchers have principally used case studies to theorize about this mechanism, this working paper validates this exposition by using an industry-level comparison, meaning our results are generalizable beyond a single meatpacking plant or community to the entire industry. Additionally, since a viable comparison group was generated, the analysis was able to track COVID-19 spread across the pandemic and observe trends against a plausible counterfactual. Our naive event study found evidence of large differences between meatpacking communities and our comparison group during the initial industry outbreak, which disappeared after implementing workplace safety precautions. Our empirical approach mirrors a recent *Journal of Public Economics* article exploring the change in labor demand resulting from the pandemic (Forsythe et al., 2020). While the working paper cannot fully verify that these newly implemented safety precautions were singlehandedly responsible for the change, this study provides suggestive evidence indicating improved working conditions led to reducing COVID-19 spread.

What did the Study Find?

- There are 49 U.S. nonmetro counties in which 20 percent or more of county employment is in meatpacking (defined in this working paper as meatpacking-dependent counties). This represents 41 percent of all nonmetro counties with employment in a single manufacturing industry greater than that threshold.
- Physical proximity of workers is nearly three standard deviations higher in the meatpacking industry compared to other manufacturers.
- Meatpacking-dependent counties observed nearly 10 times more COVID-19 cases in early May, compared to other manufacturing-dependent counties.
- By the beginning of July, this difference completely disappeared, driven by a reduction of cases in meatpacking-dependent counties.
- This identical pattern was maintained for the remainder of the study period.

How was the Study Conducted?

This analysis uses the O*NET (Occupational Information Network) to construct a complete set of working condition variables at the industry level. The analysis converts every working condition variable, from occupation to the industry in which the occupational employment statistics were gathered by the Bureau of Labor Statistics (BLS), to generate a crosswalk. The study compares the z-scores (a method used to compare meatpacking and other manufacturing industries) of the meatpacking industry to a set of other manufacturing industries most like meatpacking in terms of their employment dependence across these working condition variables. Employment dependence was defined by using imputed County Business Patterns data to determine the share of employment in single four-digit NAICS (North American Industry Classification System) industries for each nonmetro county in the United States. Using an employment threshold of at least 20 percent employment in a single manufacturing industry utilizes observed differences to generate a testable hypothesis on why the meatpacking industry experienced widespread outbreaks early in the pandemic. The analysis concludes by using the count of nationwide cases, the John Hopkins COVID-19 case data, to develop a time series to observe the different patterns in COVID-19 spread between these comparison groups of the pandemic.

Meatpacking Working Conditions and the Spread of COVID-19

Introduction

On February 26, 2020, the first non-travel related case of COVID-19 was confirmed in the United States, with limited undetected community spread since as early as late January (Jordan et al., 2020).[1] By April 1, 2020, the United States surpassed 200,000 confirmed cases (Coronavirus Research Center), and most states had begun restricting in-person work to only essential industries. Animal slaughtering and processing was one of the many industries deemed essential.[2] By early April 2020, meatpacking processing plants across the country began to experience major outbreaks of COVID-19. These processing plants soon became epicenters of the pandemic throughout the rural United States in the early months of the disease, with several plants limiting or shutting down production as a result.[3] Concerns over supply chain disruptions led to the signing of a U.S. Presidential Executive Order under the Defense Production Act on April 28, 2020 to ensure these plants remained open. Cases, however, continued to increase rapidly. By the end of May, 2020, our analysis estimates that counties with at least 20 percent of their workforce employed in the meatpacking industry comprised 13 of the 25 rural counties with the highest rates of COVID-19 per 100,000 people and 8 of the top 10.[4]

Meatpacking plants are highly concentrated in the rural United States and became prominent in the media due to the number of individuals affected. Nobles County, Minnesota, exemplified the concentration of cases within the industry. By May 1, 2020 the county reached 866 confirmed COVID-19 cases, of which 40 percent could be traced to the meatpacking plant in the county (Cummings, 2020). As a result, the plant shut down on April 21, 2020 and then partially reopened in early May 2020. At that time, the plant

---

[1] The individual became ill on February 13, 2020 but the case was not confirmed until February 26, 2020.

[2] The terms animal slaughtering, processing, and meatpacking are used interchangeably for the remainder of the paper.

[3] We will use the same classification of rural areas as Cromartie et al. (2020), defined as nonmetropolitan (nonmetro) counties. The terms "rural" and "nonmetro" are used interchangeably, as are the terms "urban" and "metro."

[4] For the list of counties, see appendix A.

began implementing policies to reduce the spread of COVID-19 through measures such as screening workers, mandating facemasks, and installing plexiglass dividers between workers (CBS Minnesota).

Nobles County, Minnesota was not an outlier. A couple of weeks earlier, a meatpacking plant in Sioux Falls, South Dakota, closed after 230 workers tested positive for COVID-19 (Corkery, 2020). This trend was so widespread in meatpacking counties that by May 6, 2020, counties within 15 miles of at least one meatpacking plant saw nearly double the number of cases per 100,000 compared to counties outside of that radius (Graddy, 2020). In many states (particularly in the Midwest, which houses many of the largest meat processing plants), much of the early COVID-19 cases initiated in these factories. Further, the reported number of cases tied to these meatpacking plants might have been underreported, according to the Milwaukee Journal Sentinel newspaper. Specifically, Brown County in Wisconsin saw significant outbreaks of COVID-19 traced to meatpacking plants, along with other high-risk establishments such as nursing homes and jails, but only a few establishments reported outbreaks (Perez, 2020; Douglas, 2020).[5] Further illustrating the widespread nature of the meatpacking industry enabling the spread of COVID-19, a similar pattern was observed in several countries in Europe during the initial outbreak of the pandemic (Middleton, 2020).

The regularity of these outbreaks (regardless of county, State, or country) indicates there were likely occupational characteristics that made meatpacking workers uniquely vulnerable to COVID-19. This paper aims to identify the mechanism that likely contributed to these outbreaks—namely, the physical proximity of workers—and evaluate the suggestive evidence that policy changes within the industry succeeded in curbing the spread of the disease.

Background

The meatpacking industry has a long history of difficult working conditions, most famously chronicled in *The Jungle* by Upton Sinclair in 1906. The book ultimately spawned many food and safety standards since it was not uncommon at the time for workers to suffer severe injuries and sometimes die on the job. While safety has improved significantly in the meatpacking industry, it includes some of the highest risks among factory jobs in the United States. Workers experience cuts, carpal tunnel syndrome, skin diseases,

[5] The outbreaks were not self-reported by the establishments. When the Milwaukee Journal Sentinel obtained access to data from Brown County, Wisconsin, the newspaper was able to trace back the cases to more facilities than were previously known.

amputations, and even death (Orrenius and Zovodny, 2009). Krumel (2017) most recently documented the industry's working conditions before COVID-19—detailing the correlation between industry wages, the contemporary deteriorating working conditions, and the shift in employment demographics from 1970-2000. During this timeframe, real meatpacking wages declined by 11 percent, while disability cases per worker increased fourfold. This result contradicted the theoretical expectation of the compensated wage differential in that as the risk increased, the wage went down. This incongruity with theory can partly be explained by the influx of Hispanic immigrants into the industry at this time, a trend that has continued into the 21st century.[6] Hispanic workers comprised 30 percent of the total workforce by 2000 and nearly 40 percent in 2020, representing many of the frontline workers at these plants (Kandel and Parrado, 2005; Champlin and Hake, 2006; Artz et al., 2010; Fremstad et al., 2020; Krumel, 2020a). Another critical factor in this change is that the industry shifted from largely specialized work to more mechanized labor. Over the last 40 years, there has also been a significant concentration of labor within the meatpacking industry, with many companies taking advantage of economies of scale to build larger processing plants (MacDonald and McBride, 2009). The increasing number of employees at these plants, as well as the declining working conditions have been offered as possible explanations for the COVID-19 outbreaks in the industry (Boehm, 2020).

A recent Proceedings of the National Academy of Sciences of the United States of America (PNAS) study provided further insight into the effects that multiple aspects of the meatpacking industry had on COVID-19 spread (Taylor et al., 2020). Notably, the authors found that transmission of the disease was highest among the counties with meatpacking plants that processed more than 10 million pounds of meat per month. These counties saw 35 percent more cases relative to the average for all counties with meatpacking plants. Most important to note for this paper is that suggestive evidence was found to show that plants receiving waivers to increase production-line processing speeds (likely requiring workers to be in closer physical proximity to each other) saw a twofold increase in transmission rates relative to

[6] Krumel (2017) demonstrates that immigrant workers might "have different compensating wage differentials from natives in the meatpacking industry," i.e., they are more willing to take these dangerous jobs at lower salaries than a comparable U.S. worker.

nonwaiver processing plants.[7] Additional context is also provided for occupational characteristics, such as physical proximity, that facilitate the spread of disease within the meatpacking industry.

There is related literature on the effect of occupational characteristics on the spread of the flu and, more recently, COVID-19. This research illustrates the impact of occupational traits on the spread of contagious diseases. Markowitz et al. (2019) documented the flu's spread and explored the spread's relationship to occupational attributes such as labor conditions, employment rates, and the prevalence of the flu. For occupational characteristics, they created an O*NET-based index containing interpersonal contact traits, such as contact with others.[8] They found that the industries with the highest interpersonal contact—i.e., health care and retail—saw the highest instances of flu transmission. In contrast, manufacturing and construction, the two industries with the lowest interpersonal contact, saw no significant flu transmission. This result differs from what is being observed with COVID-19 and its rapid spread in the manufacturing sector, driven mostly by the meatpacking industry. The conflicting results are likely due to both industrial aggregation bias (Hamermesh, 1996) and different societal reactions to seasonal flu and the COVID-19 pandemic.

Regarding the potential issue with industry aggregation bias, the index created by Markowitz and colleagues focuses exclusively on interpersonal relationships and fails to quantify any measure for physical proximity between workers or the exposure to diseases or infections. This leads to difficulties in extrapolation, especially for the meatpacking industry. Interpersonal contact is lower in meatpacking than in other manufacturing industries, but it has significantly higher physical proximity. Aggregating the industries to the sector level, rather than analyzing each individual industry, causes a downward bias in the effect of meatpacking on the spread of the virus.[9] Consequently, a more disaggregated approach is necessary to understand the role of meatpacking on the coronavirus disease spread.

---

[7] These waivers have been issued in part by technology enhancements in the meatpacking industry, as well as policy changes. The policy change occurred first in 2012 and later expanded in 2018.

[8] Contact with others is defined as: How much does this job require the worker to be in contact with others (face-to-face, by telephone, or otherwise) in order to perform it?

[9] It is important to note that the authors used two-digit North American Industry Classification System (NAICS) codes in their analysis (likely because of data availability for monthly employment numbers). For context, meatpacking is a four-digit industry classification (3116) and would have been aggregated up to manufacturing sector (31-33) in their analysis.

Regarding behavioral differences, occupations requiring high interpersonal contact (e.g., many white-collar jobs) might more easily switch to telework than those with low interpersonal contacts, such as mining, construction, and manufacturing. As a result, the contrasting response to the COVID-19 pandemic versus seasonal flu (namely, the switch to remote work if feasible) leads to valid concerns of an overestimation of risk for occupations when using just interpersonal contact.

Further research on occupational characteristics of COVID-19 spread has also shown the significance of occupational factors taking a more disaggregated approach (Lewandowski, 2020). This paper suggests the importance of occupational characteristics, such as exposure to disease and infection and physical proximity, in the early transmission of COVID-19 in the European Union. The paper's findings suggested cross-country variances in cases of COVID-19 were in large part determined by differing levels of occupational exposure (20-25 percent), while differences in containment policies played a smaller role (3.5 percent). However, as time progressed past the first 7 days after the 100th case was identified in country, the contribution that differences in occupational exposure had on the spread of the disease decreased, and the contribution that containment policies had on slowing the spread increased. Like the Markowitz study, this paper also creates an index that is partly correlated with the ability to work from home, as Lewandowski used four European Working Condition Survey variables in the index, which measured interpersonal relationships and the place of work.

Lewandowski (2020) provides evidence suggesting that, as time progresses, both countries and businesses could reduce occupational risk. This result is partly corroborated by the findings in the PNAS article showing meatpacking plants that closed their businesses had transmission rates lower than counties without meatpacking plants 3 weeks after the closure. This delay is likely due to an incubation period of up to 14 days (Taylor et al., 2020). Combined, these results, therefore, provide evidence suggesting COVID-19 prevention policies implemented by firms helped reduce the spread of the disease.

Data

Our dataset was developed to identify the occupational characteristics that could have driven COVID-19 cases within the meatpacking industry, motivated by the previous work on occupational characteristics and their relationship to the spread of the flu and COVID-19. Three different data sources were combined to conduct the analysis: employment by industry at the county level, occupational characteristics, and confirmed COVID-19 cases at the county level. Using this collected information, a naive event study was evaluated that centered around COVID-19 cases within rural counties with a high employment share in the meatpacking industry, compared to other rural counties similarly dependent on other single-industry manufacturing.

County-Industry Dependence

To develop our comparison groups, two indicator variables were created based on the industry's employment share within a county using the North American Industry Classification System (NAICS) and imputed County Business Patterns data (Eckert et al., 2020). A county is defined as dependent on a single industry if said industry employs 20 percent or more of the county's total employed workers. To construct a plausible counterfactual, this analysis is restricted to all manufacturing industries with a similar employment dependence to maintain comparability to develop our meatpacking indicator.[10] The aim was to isolate the impact from a single large facility, not a combined effect from multiple plants and aggregated industries.[11,12] All counties not containing at least 20 percent employment in a single manufacturing industry were dropped from our analysis.

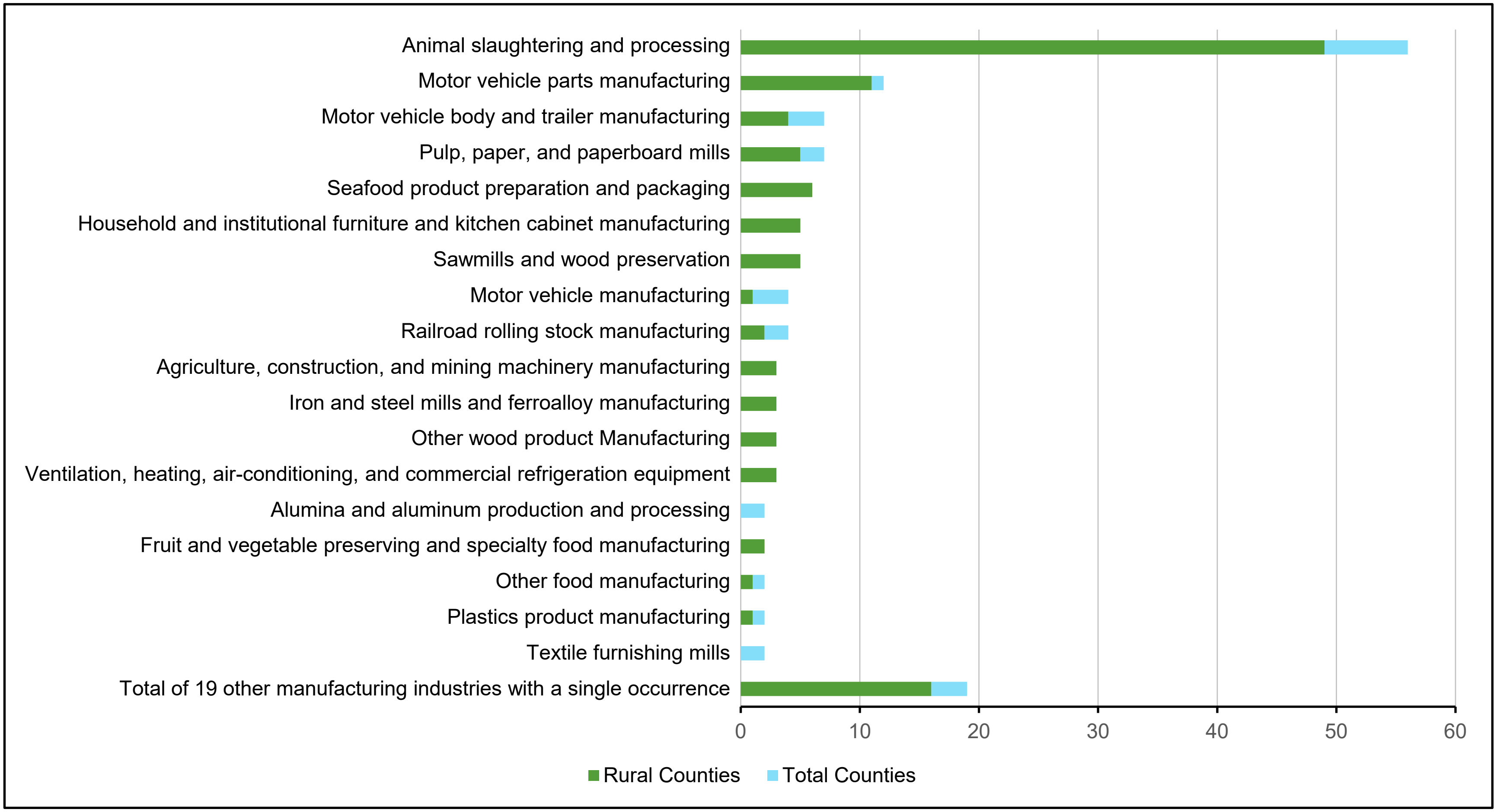
[10] For a comparison group, we wanted employment that would have the most similar working conditions to meatpacking and considered essential (meaning that most jobs were not moved to remote). Manufacturing as a sector fits this description.

[11] We are assuming that it will be possible to pick up the effect from a plant outbreak using such a high level of employment dependence. This assumption appears to be corroborated in the case of Nobles County, Minnesota—where it is estimated that the meatpacking plant accounted for 40 percent of total cases as of May 1, 2020.

[12] We should note that USDA, Economic Research Service has an alternative definition of manufacturing dependence, which uses total manufacturing employment across multiple industries. All our results are robust to the relaxing the definition of manufacturing dependence to a single industry and using this more general classification.

Figure 1

Number of counties with more than 20 percent of employment in a single 4-digit North American Industry Classification System, manufacturing category



Source: USDA, Economic Research Service using data from Eckert, F., Fort, T. C., Schott, P. K., and Yang, N. J. 2020. Imputing Missing Values in the U.S. Census Bureau's County Business Patterns, No. w26632. National Bureau of Economic Research.

In total, 147 counties were identified as being dependent upon a single manufacturing industry. Of these, 120 counties (82 percent) are nonmetro. As figure 1 demonstrates, the meatpacking industry comprises a significant share of these nonmetropolitan counties. Since nearly 90 percent of meatpacking-dependent counties are nonmetro, the sample is restricted to the rural subsample for comparability.[13] As such, these 120 counties functioned as our sample of analysis for the remainder of the paper. Further illustrating this concentration is that these meatpacking-dependent counties represent just 2.5 percent of all rural counties but 19.0 percent of all meatpacking employment in the United States (Cromartie et al., 2020). This representation stems from a significant consolidation within the meatpacking industry over the past 40 years. Other major industries represented in manufacturing-dependent counties categorization include motor vehicle manufacturing, lumber mills, and seafood product preparation. However, these industries employ 20 percent or more of the total workforce in at most only 11 rural counties. Since the sample size of all non-meatpacking, single-industry manufacturing-dependent counties are much smaller than meatpacking, all of these counties were pooled into a single comparison group.

Our sample was limited to strictly rural counties. In addition to the reasons discussed above, this restriction enhanced our ability to identify mechanisms of the disease spread. Cromartie et al. (2020) showed that rural counties demonstrated flat and uniform patterns of COVID-19 case spread through June 2020. In other words, this pattern held regardless of population size. By contrast, metro counties showed a large initial spike in April 2020 and a substantial caseload decrease through June 2020. Due to this lack of homogeneity between rural and metro counties in the timing of the pandemic, it becomes unfeasible to determine if differences in COVID-19 spread are attributable to industry dependence or other confounders correlated with metro status. This finding should not reduce our external validity—as only 7 of the 56 meatpacking counties observed in this study, or 12.5 percent, are metro counties.

Occupational Characteristics

This working paper used data collected on more than 1,000 occupations from O*NET (O*NET OnLine) to construct our data on occupational characteristics among manufacturing industries. Three different work context topics were used for our analysis: interpersonal relationships, physical work conditions, and structural job characteristics. These categories represent 57 different variables, which provide a wealth of information on the characteristics of these occupations. O*NET collects this data by randomly sampling

[13] Meatpacking-dependent counties include 49 nonmetro and 7 metro counties.

employees from each of these occupations, as well as employers. The three variables most likely to enable the spread of viruses are contact with others, physical proximity, and exposure to disease or infection. In other words, how much the job requires workers to be in contact with others (face-to-face, by telephone, or otherwise),[14,15] the extent to which the job requires workers to be in close physical proximity to others,[16] and how often the job requires exposure to disease or infection,[17] respectively. Unlike the previous literature, however, we did not create a combined index, but instead, all 57 variables were evaluated independently to assess significant occupational outliers in the meatpacking industry that could enable the spread of the disease and avoid issues with creating an aggregated index.

Since the data collected from O*NET is gathered at the occupational level, and our analysis was at the industry level, the occupational data were first converted to the industry level.[18] Occupational employment statistics gathered by the U.S. Bureau of Labor Statistics (BLS) were used to facilitate our conversion process. BLS collects the occupational data from employers in all industry sectors and geographic areas throughout the United States. These industries comprise occupations designated by their 6-digit occupation code. Using this 6-digit occupation code, a crosswalk was constructed between the data from BLS and O*NET to match the occupations with their respective work context score. By doing so, most occupations were matched within each industry on a first pass, although some industries initially matched under 90 percent of the occupations.

---

[14] Since the formal definition for the work context involves contact with others (i.e., face-to-face, by telephone, or otherwise) this variable will be difficult to interpret in light of COVID-19. It is not feasible to separate occupations with high in-person contact and occupations easily able to switch to remote.

[15] The first quintile is no contact with others, second quintile is occasional contact with others, third quintile is contact with others about half the time, fourth quintile is contact with others most of the time, and the final quintile is constant contact with others.

[16] First quintile workers do not work near other people (beyond 100 feet), second quintile workers work with others but not closely (e.g., private office), third quintile workers work slightly close to others (e.g., shared office), fourth quintile workers work moderately close others (at arm's length), and the final quintile workers work very close to others (near touching).

[17] First quintile workers almost never come into contact with diseases or viruses, second quintile workers are exposed at least once a year or more (but not every month), third quintile workers are exposed once a month or more (but not every week), fourth quintile workers are exposed once a week or more (but not every day), and the final quintile workers are exposed every day.

[18] To the best of our knowledge, we are the first to utilize this approach to evaluate the role of working conditions in industry-related outcomes. Such data has broader applications, beyond COVID-19, that future research should explore.

The lower match rates for some industries can largely be attributed to the O*NET database lacking information on some occupations that comprise occupations within industries and suppressing data on occupations with insufficient total employment numbers. To combat this issue, weighted averages were created based on similar occupations that had O*NET scores. Determining similarity in occupations was done by matching the digit on the occupational code. For instance, occupations with the same first five digits are grouped together. Once an occupation was matched to other similar ones, a weighted average was computed based on the number of individuals employed with O*NET data. If no matches were found at the 5-digit level, the same process would be repeated with four digits, and so forth. Using this method, nearly 99 percent of occupations were matched with all industries for all work context variables. These occupational characteristics were then aggregated to the industry level by calculating the weighted average of the occupations that compose it.

COVID-19 Cases

Our paper uses county-level confirmed COVID-19 case data collected from Johns Hopkins University (Dong et al., 2020) as a primary outcome measure. Johns Hopkins collects its data from aggregated data sources, such as the Centers for Disease Control and Prevention, as well as from State and county health departments. The reported data are cumulative totals, from which the daily growth for each county is calculated. A 2-week moving average was next calculated to both smooth the data and minimize issues with corrections in the Johns Hopkins data. Specifically, the data has dates for counties that were corrected to account for either under- or over-reporting of COVID-19 cases in previous days. Furthermore, to allow for comparability among counties, county population was used to weight cases using the U.S. Department of Commerce, Bureau of the Census's 2019 county population estimates. Our measure was then defined as the 2-week moving average of daily COVID-19 cases per 100,000 people. The ratio of this 2-week-moving average number of new daily cases was taken for the point estimate for our naive event study.

This variable was constructed over the timeframe spanning from mid-March to mid-September 2020. The analysis begins in mid-March since it was not until this point that confirmed cases became national in scope. Cases reported past mid-September were excluded in our primary analysis since a massive surge in rural areas occurred at this time, and it cannot be determined whether it was caused by individual manufacturing plants or an overall nationwide surge in those geographies. This temporal restriction was made for the sake of identification. As the sample sizes were relatively small, our results will be severely impacted by noise correlated with this surge.[19] Cromartie et al. (2020) extended their analysis through November 2020 on a larger comparison group. They suggested that this surge does not appear to be driven by the meatpacking industry, since the pattern within that industry appeared nearly identical to all other rural counties.[20]

Results[21]

In early March 2020, before these widespread outbreaks, meatpacking-dependent counties started with fewer COVID-19 cases compared with counties dependent on other manufacturing industries. However, the number of cases in meatpacking-dependent counties proceeded to increase significantly, relative to the comparison group over the rest of the month, through the end of May 2020. Beginning in early June 2020, there was a sharp decline relative to the comparison group, converging toward no difference in the number of cases. The timing of this decline corresponds with adjustments in working conditions made by the industry. By mid-July 2020, there was no difference in spread rate between meatpacking-dependent counties and other manufacturing-dependent counties in COVID-19 case numbers. This pattern remained consistent through the remainder of our examined timeframe.

---

[19] As we will demonstrate in our results section, from July 17 through September 17, 2020, COVID-19 cases in meatpacking-dependent counties were an average of less than 1 percent higher than manufacturing-dependent counties. For comparison, from mid-September through the end of 2020, cases in meatpacking-dependent counties were 11 percent higher. This difference offers a significant challenge in identification because there was not a monotonic pattern. In October, cases in meatpacking-dependent counties were 31 percent higher. This fell to 7 percent higher in November, and meatpacking-dependent counties were actually 12 percent lower than the comparison group in December. It could be the case that there were systematic differences related again to industry working conditions, or it could be random noise, driven by our relatively small sample size and idiosyncratic rural spread, which was not picked up by the industry. Because of the rising case prevalence across rural communities, we do not feel comfortable performing this inference, but subsequent research should better aim at decomposing the spatial and temporal spread in rural areas of the United States. To supplement this analysis, appendix B provides the 2-week moving average of new daily COVID-19 cases, per 100,000 population, for our 2 categories through the end of 2020.

[20] It is important to note the critical distinction between the analyses presented in Cromartie et al. (2020) and this paper. Our study employs the same definition of meatpacking dependence, but Cromartie et al. (2020) compare meatpacking-dependent counties to all other rural counties. That is a critical descriptive exercise that provides vital context to the pandemic scope and is the proper comparison for *Rural America at a Glance (*et al., 2020). In addition, this study controls for working conditions in order to better understand the factors that may have caused greater transmission in the meatpacking industry.

[21] An earlier version of this analysis utilized a lagged dependent variable model; however, since the Arellano-Bond estimator cannot be employed (because the variables we are most interested in interpreting are time-invariant), there are legitimate endogeneity concerns with such a framework. This led us to simplify the analysis for our preliminary findings.

Occupational Characteristics

Our analysis started by analyzing occupational characteristics to generate our testable hypothesis: i.e., that meatpacking-dependent counties had higher COVID-19 spread than other manufacturing-dependent counties and likely attributable to the working conditions in meatpacking plants. We identify the mechanism that likely caused a higher impact of COVID-19 throughout the meatpacking industry, compared with other industries and the counties where they are located. We use O*NET data, as discussed above to conduct this analysis, specifically comparing occupational characteristics between the meatpacking industry and other manufacturing-dependent industries. This comparison was conducted by analyzing z-scores of the meatpacking industry, calculated against the sample of all similarly dependent industries in at least one rural county.

Table 1

Meatpacking working condition scores and number of standard deviations from the comparison sample's mean

Work context	Meatpacking dependent	Manufacturing dependent	Meatpacking z-score
Physical proximity	66.64	57.72	2.78
Exposed to disease or infections	14.75	8.16	2.58
Spend time making repetitive motions	70.25	58.27	2.45
Deal with physically aggressive people	13.46	9.45	1.91
Spend time standing	79.89	65.93	1.75
Spend time using your hands to handle, control, or fell objects, tools, or controls	80.92	70.99	1.64
Pace determined by speed of equipment	61.28	44.96	1.64
Deal with unpleasant or angry people	50.41	44.86	1.51
Very hot or cold temperatures	59.76	46.07	1.49
Spend time bending or twisting the body	54.63	44.37	1.48
Work with work group or team	81.68	78.98	1.42
Wear common protective or safety equipment	84.64	75.42	1.30
Consequence of errors	55.23	49.54	1.25
Deal with external customers	50.94	45.10	1.22
Indoors, environmentally controlled	71.81	62.60	1.21
Frequency of decision making	73.13	69.87	0.91
Exposed to whole body radiation	13.68	10.65	0.88
Coordinate or lead others	64.55	62.48	0.86
Responsibility for outcomes and results	62.34	60.48	0.75
Wear specialized protective or safety equipment	29.93	25.68	0.74
Degree of automation	35.55	32.86	0.69
Level of competition	49.89	48.46	0.57
Exposed to hazardous equipment	55.33	51.15	0.55
Exposed to minor burns, cuts, bites, or stings	44.68	41.58	0.52
Spend time walking and running	50.42	47.45	0.48
In an enclosed vehicle or equipment	26.70	24.61	0.46
Outdoors exposed to weather	33.07	30.17	0.41
Spend time keeping or regaining balance	18.40	17.58	0.30
Time pressure	77.12	76.67	0.27
Importance of repeating same tasks	59.48	58.66	0.24
Responsibility for other's health and safety	63.18	61.96	0.24
Duration of typical work week	69.39	69.05	0.10
Extremely bright or inadequate lighting	30.39	30.66	-0.07
In an open vehicle or equipment	23.27	23.76	-0.08
Cramped workspace, awkward positions	31.28	32.54	-0.26
Exposed to high places	21.37	22.67	-0.27
Spend time climbing ladders, scaffolds, or poles	14.06	15.24	-0.38
Frequency of conflict situations	42.25	43.36	-0.43
Work schedules	12.78	13.79	-0.49
Letters and memos	39.56	41.80	-0.53
Importance of being exact or accurate	80.17	80.84	-0.53
Outdoors, under cover	16.39	19.03	-0.57
Exposed to contaminants	56.61	61.72	-0.71
Public speaking	20.04	23.35	-1.15
Exposed to radiation	2.23	3.97	-1.25
Telephone	50.72	59.24	-1.26

Work context	Meatpacking dependent	Manufacturing dependent	Meatpacking z-score
Sounds, noise levels are distracting or uncomfortable	58.98	66.22	-1.27
Indoors, not environmentally controlled	40.16	50.25	-1.31
Exposed to hazardous conditions	29.09	36.14	-1.32
Electronic mail	34.29	49.60	-1.45
Spend time kneeling, crouching, stooping or crawling	20.20	25.79	-1.47
Impact of decisions on co-workers or company results	62.69	67.19	-1.90
Spend time sitting	22.32	38.89	-1.93
Structured versus unstructured work	62.83	70.07	-2.24
Face to face discussions	83.66	89.20	-2.61
Contact with others	72.20	79.61	-2.70
Freedom to make decisions	61.47	72.29	-2.93

Note: Values above 1.645 represent a confidence level of 90 percent or above, values above 1.96 represent confidence levels of 95 percent or above, and values of 2.576 represent a confidence level of 99 percent or above.

Source: USDA, Economic Research Service using data from O*NET OnLine (n.d.), National Center for O*NET Development.

Of the 57 working-condition variables analyzed, evidence of significant differences was found in 13 of them. As table 1 illustrates, the meatpacking industry is a significant outlier on all factors the previous literature indicated as enabling the spread of a virus. The most significant of these is physical proximity, being nearly three standard deviations away from the sample's mean. This calculation and the size of the score suggest that workers within these meatpacking plants frequently work significantly closer together than other manufacturing workers. Beyond being nearly 3 standard deviations higher than the sample mean, the estimated value of 66.64 indicates that the average worker in meatpacking is an arm’s length away from their coworkers.

Because the mean score over the entire industry is used to facilitate the additional analysis, certain occupations (executives) will reduce this average, and this fact is observed prominently in meatpacking. To contextualize the score above, the three production occupations that make up more than a third of the total employment—meat, poultry, fish cutters and trimmers; butchers and meat cutters; and slaughterers and meat packers—have scores of 85, 77, and 73, respectively. So, while the average worker is an arm’s length away from their coworkers, the modal worker is significantly closer. These frontline workers are the main reason meatpacking is nearly three standard deviations above our sample’s mean.

Another key difference between meatpacking and other manufacturing jobs is the high score on exposure to disease and infection, which is nearly 2.5 standard deviations above the mean. This score can likely be attributed to workers at meatpacking plants coming into contact with foodborne illnesses, such as

Salmonella.[22] While foodborne illnesses spread through different channels than a coronavirus, this still represents a significant difference between meatpacking and other manufacturing industries.

Contact with others is another variable that was found to enable the spread of the flu, and other literature used it to forecast and evaluate COVID-19 spread. Meatpacking was 2.70 standard deviations below the mean in this category. Providing additional context for this score, meatpacking was also 2.61 standard deviations below the mean for face-to-face conversations, compared to the sample of other manufacturing industries. The deskilling that meatpacking underwent starting in the 1970s, as the industry became increasingly mechanical through the utilization of repetitive tasks, appears to have minimized interaction among workers. This is not to say that there are not points in the day when contact with others will occur at a high rate, such as breaks and shift changes. However, when performing individual work responsibilities, contact with others was significantly lower than that found in the comparison group of manufacturing industries.

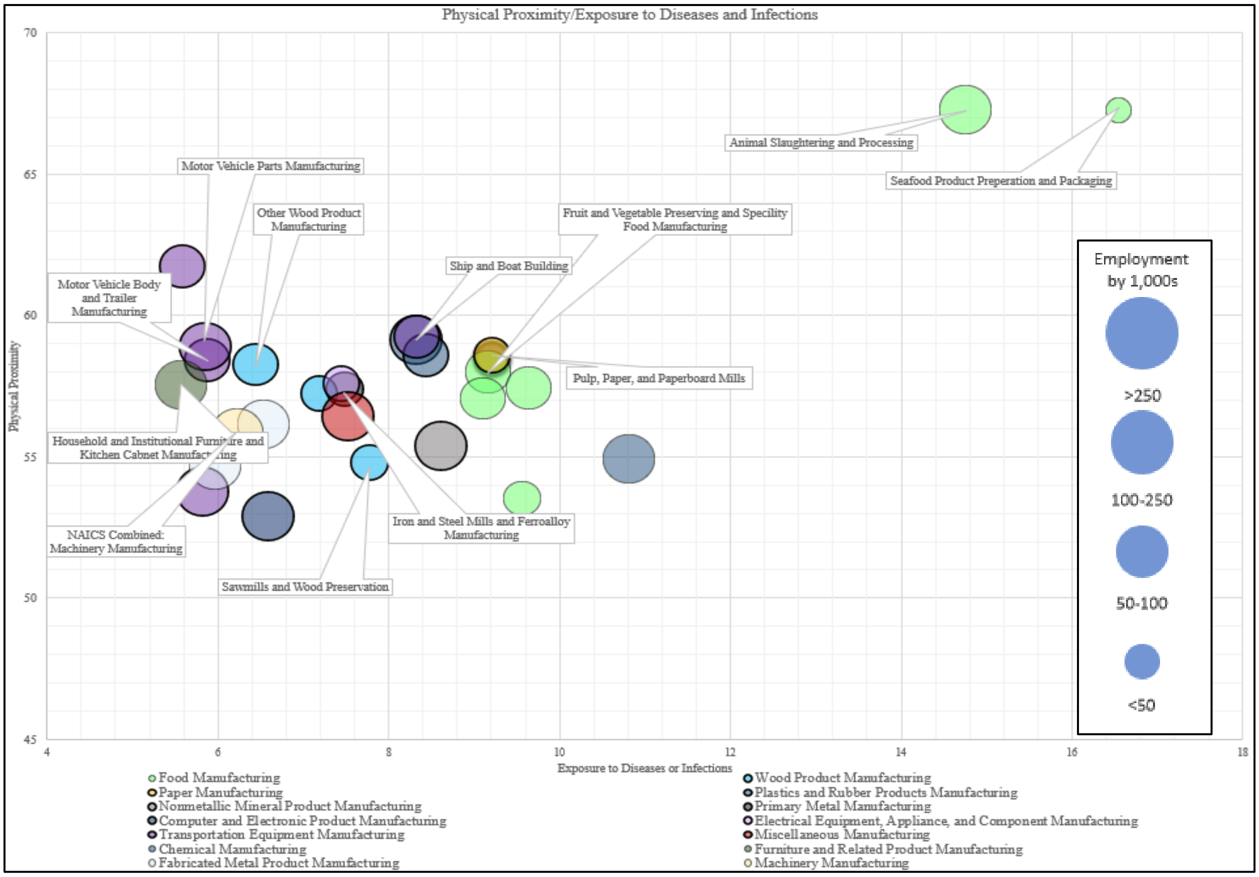
Bolstering confidence in our developed measure of classifying working conditions, scores of more than 1.645 standard deviations above the mean were observed for meatpacking, compared with other manufacturing-dependent industries for the following variables as well: 1) Time spent making repetitive motions, 2) Time spent standing, 3) Time spent using your hands to handle, control or fell, objects, tools, or controls, and 4) Pace determined by speed of equipment. Scores of more than 1.645 standard deviations were observed below the mean for meatpacking, compared with other manufacturing-dependent industries on: 1) Freedom to make decisions, 2) Structured versus unstructured work, 3) Time spent sitting, and 4) Impact of decisions on coworkers or company results.

The differences in working conditions between the meatpacking industry and other manufacturing plants indicate aggregation bias (i.e., combining multiple industries) that can mask important differences across industries.

[22] It is also worth mentioning that, while this value differs significantly from that seen in our comparison sample of other manufacturing, it is still a relatively low value. This indicates that meatpacking workers are exposed fairly infrequently.

Figure 2

Scatter plot of physical proximity of workers, exposure to diseases and infections, and total industry employment



Note: We would like to point out that there is a tight clustering of the other industries on physical proximity between 55 and 60. There are only 3 industries above 60, with meatpacking and seafood processing being the only 2 industries above 65.

Source: USDA, Economic Research Service using data from O*NET OnLine (n.d.), National Center for O*NET Development.

Figure 2 shows two of the three characteristics previously used in the literature to forecast and explain that viral spread in the workplace was significantly more prevalent in the meatpacking industry relative to the other manufacturing industries. Focusing on these two occupational characteristics, figure 2 displays the distribution of manufacturing industries that have a rural employment dependence with respect to their values for physical proximity and exposure to diseases, as well as industry size. As shown, there is significant clustering of manufacturing industries around the scores of 58 (Slightly close—e.g., shared office) and 7 (almost never exposed) for physical proximity and exposure to diseases and infections, respectively. Of industries that also have a rural manufacturing-dependent county, only animal slaughtering and processing and seafood product preparation and packaging were significant outliers, with meatpacking having significantly higher total employment.

Table 1 and figure 2 provide strong evidence that the outbreaks within the meatpacking industry can likely be attributed to workers' uniquely high physical proximity. They also raise the possibility that meatpacking might be more susceptible to disease and virus outbreaks generally. However, further work should aim at distinguishing the possible contributions from foodborne and airborne illnesses. While other characteristics, such as low temperatures or a loud work environment could lead to higher rates of COVID-19 spread, neither factor was found to significantly vary between meatpacking and other manufacturing industries. In the case of a loud work environment, which may increase the spread of the disease due to increased particle admission when having to shout, meatpacking was below the sample average (Asadi et al., 2019).

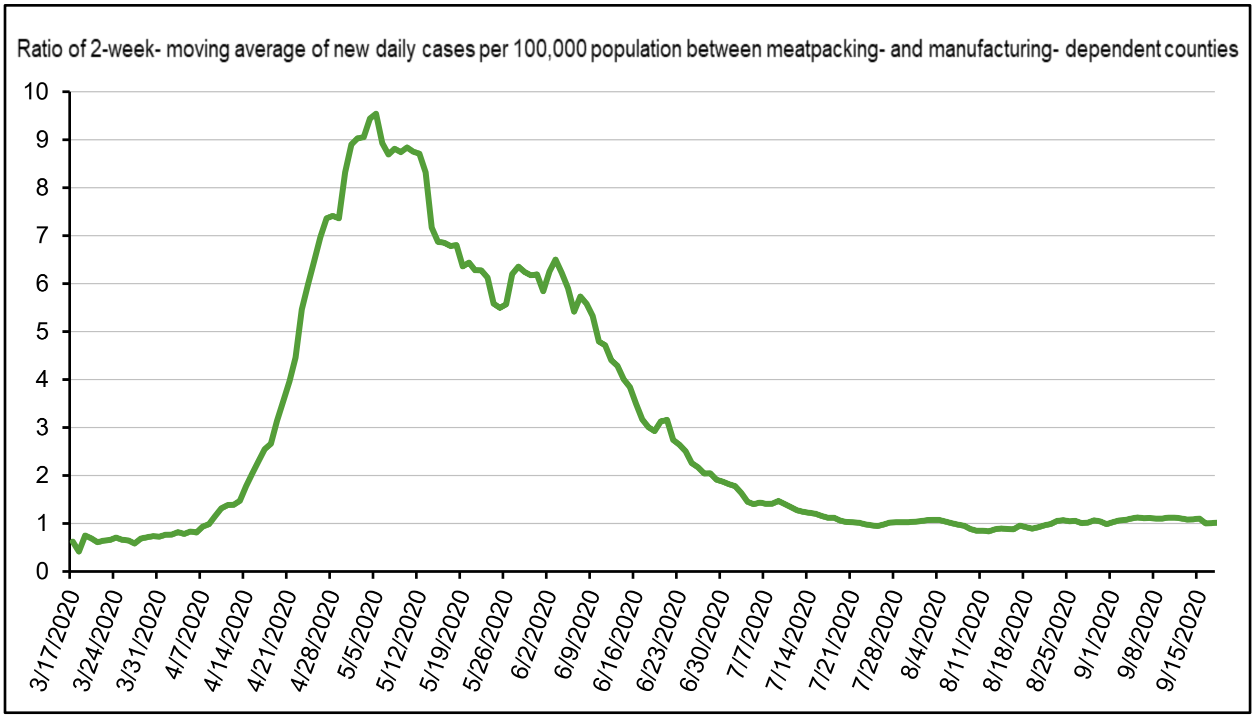
Supplementing these results are the findings from Taylor et al. (2020) that meatpacking companies that had received a waiver to increase production speeds saw increased rates of COVID-19 compared with plants that received no such waiver. Plants with higher line speeds (i.e., faster equipment) likely also necessarily increased physical proximity between their workers. Günther et al. (2020) documented the spread of COVID-19 at a single large meatpacking plant, highlighting the importance of physical proximity in the spread of the disease. They found evidence that cases that spread within the plant had a significant spatial pattern. Specifically, there was significant transmission of COVID-19 to co-workers working within close physical proximity. Using information collected on living conditions and transportation of individuals at this meatpacking plant, their data also strongly suggested that while there may have been secondary infections outside of work, transmission most likely occurred at the processing plant. Extrapolating their findings to our results, inference that many of the cases observed in our meatpacking-dependent counties occurred via close physical proximity to workers with COVID-19 and likely not through secondary infections from outside the processing plant.

Further complementing our results is an additional report from the CDC, which evaluated a single meatpacking plant in South Dakota (Steinberg et al., 2020). This report found frontline workers, who often work in close proximity to one another, had higher case rates of COVID-19 compared with other workers. Furthermore, salaried workers who had individual workstations (thus enabling them to increase physical distance and implement physical barriers) experienced lower rates relative to hourly workers with less access to such amenities. While the CDC focused on a single meatpacking plant, it provides anecdotal context supporting our findings. Since industry-specific data was analyzed, our results are likely valid for the entire industry at large in that the physical proximity of workers was a primary driver of the COVID-19 outbreaks experienced across meatpacking.

COVID-19 Cases in Rural Meatpacking Counties

Figure 3

Ratio of new COVID-19 cases since March 17, 2020: Comparing rural counties with employment rates of 20 percent or more in meatpacking to rural counties with employment rates of 20 percent or more in other single manufacturing industries, 2-week-moving average of new daily COVID-19 cases



Sources: USDA, Economic Research Service using data from Johns Hopkins University Coronavirus Resource Center. (n.d.) Center for Systems Science and Engineering, Johns Hopkins University and Medicine, Baltimore, Maryland; Eckert, F., Fort, T. C., Schott, P. K., and Yang, N. J. 2020. Imputing Missing Values in the U.S. Census Bureau's County Business Patterns, No. w26632. National Bureau of Economic Research.

Figure 3 illustrates the ratio of cases between meatpacking- and other manufacturing-dependent counties as defined above.[23,24] As shown in this figure, the caseloads between the two groups were similar until mid-April 2020, with meatpacking-dependent counties starting a slight decline in new COVID numbers.

[23] Since we are presenting our results as a ratio (meatpacking divided by manufacturing), it is worth mentioning that meatpacking and other manufacturing are equal at a value of 1. Greater than 1 means that meatpacking is higher than manufacturing, while a value of less than 1 signifies that meatpacking is lower than manufacturing.

[24] Appendix B tracks the data as separate categories rather than presenting the ratio.

At this time, cases began to climb substantially within rural meatpacking-dependent counties relative to all other rural manufacturing-dependent counties. The peak of this disparity occurred in early May 2020, with meatpacking-dependent counties having nearly 10 times as many cases per day, compared with the other counties in our study.[25] During the next 2 months, there was a significant drop until early July 2020, at which point both groups of counties experienced almost identical caseloads for the remainder of our data frame. It should be noted that there was an increase in COVID-19 cases in other manufacturing-dependent counties during May and June 2020; however, the growth was substantially smaller than the decrease in daily cases in meatpacking-dependent counties during the end of May through June 2020.[26] Therefore, figure 3 provides suggestive evidence that there was some change within these meatpacking-dependent counties driving this drop, rather than being driven by an increase in cases from the other manufacturing-dependent counties.[27,28]

Possible Effects of Industrial Changes

Extrapolating from our analysis of the occupational characteristics of meatpacking and naive event study of cases, inference of the effect of industry-wide changes within these counties on COVID-19 transmissions can be made. Specifically, using cases from the naive event study, a crucial shift in the reaction to COVID-19 can be evaluated. As shown in figure 3, after the initial peak in cases in late April through early May 2020, the disparity between meatpacking and other manufacturing-dependent counties

[25] Our results are somewhat dampened compared to Cromartie et al. (2020), suggesting that our manufacturing-dependent counties had at least marginally higher caseloads when compared to non-manufacturing rural counties.

[26] On June 3, 2020, the start of the convergence, meatpacking-dependent counties had a 2-week-moving average of daily cases of 38, compared to 6 for our comparison group. On July 21, 2020, our data appear to stabilize at around 2-week moving average of daily cases of 19 for both groups. For the next 2 months, the 2-week moving average of daily cases is bounded between a low of 15 and a high of 22. A temporary steady-state appears to be achieved, suggesting the convergence was not driven by our comparison group increasing.

[27] These results are robust. Several alternative constructions of the time series are not included in the preliminary version of this manuscript: 1) They are robust to aligning counties by point in the epidemiological disease progression, eliminating concerns about statewide spread driving the measured results. 2) They are robust to using the neighboring rural counties to address some of the unobserved factors likely to be shared across neighboring counties. 3) It is further demonstrated that meatpacking plants are likely the vector of observed county-level spread by relaxing the employment threshold, indicating a monotonically decreasing pattern, as meatpacking employment becomes less prominent in a county. 4) The results are robust to the utilization of deaths as the variable of interest, indicating that testing is not driving the analysis. 5) The results are also externally valid to utilizing a distinct dataset with COVID-19 cases by meatpacking workers and workers in other food processing, exhibiting an identical temporal pattern.

[28] The results are also robust to county characteristics, as demonstrated by a multivariable-conditional correlation on the initial outbreak.

started to decrease sharply, moving identically for the final 2 months of the study. This similarity provides suggestive evidence that policy changes within these plants, such as installing physical barriers between workers and requiring workers to wear face masks, helped reduce the transmission of COVID-19 cases within these meatpacking plants. This inference is shared by Cromartie et al. (2020): "[P]artial plant closures and increased social distancing protocols were implemented at meatpacking plants across the country starting in late May 2020. These measures appear to have slowed infection rates, as June saw a sharp reduction in cases in meatpacking-dependent counties."

Data collected on 111 different meatpacking plants in 14 states by the CDC during April and May 2020 provide in-depth information on the type of policies that processing plants implemented during these months to control the spread of COVID-19 (Waltenburg et al., 2020). Specifically, the CDC found 80 percent of facilities in their sample screened workers on entry; 77 percent required face masks; and 62 percent installed physical barriers. Some of these plants' procedures would have directly affected the spread of cases caused by workers' close physical proximity (i.e., physical barriers and face masks). However, policies such as removing financial incentives and decreased crowding of transportation were often not implemented, 30 percent and 15 percent, respectively. The financial incentives are an industry policy that could receive additional attention from researchers in the future. On the one hand, the industry compensated their workers for the additional risk of contracting the virus by providing hazard pay. On the other hand, workers within the meatpacking industry are often financially constrained and thus uniquely dependent upon working (Krumel, 2020b). This hazard pay could have created the incentive for individuals who are feeling sick to still show up for work.

While this type of prevention effort was not universal, the information provides evidence that many meatpacking plants began to implement prevention policies during the pandemic's early months. Given the sharp decline of cases seen within the data while implementing these policies, the data provide suggestive but meaningful evidence that the implementation of policies (such as universal face masks and physical barriers) reduced COVID-19 spread within meatpacking plants.

Discussion

To our knowledge, this paper represents the first effort to empirically identify the mechanism that likely caused the COVID-19 outbreaks within the meatpacking industry at an industry-level analysis. There is strong evidence the meatpacking industry was a major catalyst for COVID-19 outbreaks in rural America during the pandemic's early months. This evidence indicates these outbreaks were likely attributable to workers' physical proximity within these plants. Suggestive evidence is also found that shows policies introduced within these plants in the wake of the outbreaks helped reduce the future spread of the disease.

Meatpacking plants were already incredibly vulnerable to the spread of COVID-19 due to consolidation within the industry, which led to large meatpacking processing plants with hundreds of workers. This was further exacerbated by the close physical proximity of workers within these plants, which helped to facilitate the disease’s spread—especially among frontline workers. Despite past warnings to prepare for a scenario such as COVID-19 within the food industry (Grabell and Yeung, 2020), COVID-19 represents a largely exogenous shock, which resulted in delayed responses throughout many occupations and industries.

References

Artz, G., Jackson, R., and Orazem, P. F. 2010. "Is It a Jungle Out There? Meat Packing, Immigrants, and Rural Communities," *Journal of Agricultural and Resource Economics*, 35(2), 299-315.

Asadi, S., Wexler, A.S., Cappa, C.D., Barreda, S., Bouvier, N., and Ristenpart, W. 2019. "Aerosol emission and superemission during human speech increase with voice loudness," *Sci Rep* 9, 2348.

Boehm, R. 2020, May 20. "With Trump Executive Order, Are Meat and Poultry Plants a COVID-19 Ticking Time Bomb?," *Union of Concerned Scientists*.

CBS Minnesota. "Coronavirus in MN: Worthington's JBS Pork Plant Partially Reopens, Operations Expected to 'Normalize Over Time.'" CBS Network, Minnesota.

Champlin, D., and Hake, E. 2006. "Immigration as industrial strategy in American meatpacking," *Review of Political Economy*, 18(1), 49-70.

Corkery, M. 2020, April 13. "U.S. Food Supply Chain is Strained as Virus Spread," *The New York Times*. New York, New York.

Cromartie J, Dobis E, Krumel Jr, T. P., McGranahan D, and Pender J. 2020. *Rural America at a Glance 2020 Edition*, EIB-221. U. S. Department of Agriculture, Economic Research Service. December 2020.

Cummings C. 2020. "Coronavirus in Minnesota: Nobles County Reaches 866 Known Cases of COVID-19, Most Traced to JBS Pork Plant." CBS Network, Minnesota.

Dong E, Du H, and Gardner L. (n.d.) "An interactive web-based dashboard to track COVID-19 in real time," *Lancet Infectious Diseases,* 20(5):533-534.

Douglas, L. 2020. "As more meatpacking workers fall ill from COVID-19, meat companies decline to disclose data," *The Fern*.

Eckert, F., Fort, T. C., Schott, P. K., and Yang, N. J. 2020. *Imputing Missing Values in the U.S. Census Bureau's County Business Patterns,* No. w26632. National Bureau of Economic Research.

Fremstad, S., Rho, H., and Brown, H. 2020. *Meatpacking Workers are a Diverse Group Who Need Better Protections.* Center for Economic and Policy Research, Washington D.C.

Forsythe, E., Kahn, L. B., Lange, F., and Wiczer, D. 2020. "Labor demand in the time of COVID-19: Evidence from vacancy postings and UI claims," *Journal of Public Economics*, 189, 104238.

Grabell, M. and Yeung, B. 2020 "Meatpacking Companies Dismissed Years of Warnings but Now Say Nobody Could Have Prepared for COVID-19." ProPublica, New York, New York.

Graddy, S. 2020. *Investigation: Counties with Meatpacking Plants Report Twice the National Average Rate of COVID-19 Infections*. The Environmental Working Group, Washington D.C.

Günther, T., Czech-Sioli, M., Indenbirken, D., Robitaile, A., Tenhaken, P., Exner, M., Ottinger, M., Fischer, N., Grundhoff, A., Mrinkmann, M. 2020. "SARS-CoV-2 outbreak investigation in a German meat processing plant," *EMBO Molecular Medicine*.

Hamermesh, D. S. 1996. *Labor Demand*. Princeton, New Jersey: Princeton University press.

Johns Hopkins University Coronavirus Resource Center. (n.d.) Center for Systems Science and Engineering, Johns Hopkins University and Medicine, Baltimore, Maryland.

Jorden, M. A., Rudman, S. L., Villarino, E., Hoferka, S., Patel, M. T., ... and Mytty, E. 2020. "Evidence for Limited Early Spread of COVID-19 Within the United States, January–February 2020," *Morbidity and Mortality Weekly Report*, 69(22), 680.

Kandel, W., and Parrado, E. A. 2005. "Restructuring of the US meat processing industry and new Hispanic migrant destinations," *Population and Development Review*, 31(3), 447-471.

Krumel Jr, T. P. 2017. "Anti-Immigration Reform and Reductions in Welfare: Evidence from the Meatpacking Industry," *Choices,* 32(1), 1-7.

Krumel Jr, T. P. 2020. Three Essays on Welfare and Experimental Economics. Ph.D. dissertation. University of Connecticut - Storrs.

Krumel Jr, T. P. 2020. *The Meatpacking Industry in Rural America During the COVID-19 Pandemic*, U.S. Department of Agriculture, Economic Research Service, Washington D.C.

Lewandowski, P. 2020. *Occupational Exposure to Contagion and the Spread of COVID-19 in Europe*. Institute of Labor Economics.

Macdonald, J. and McBride, W. 2009. *The Transformation of U.S. Livestock Agriculture: Scale, Efficiency, and Risks*, EIB-43. U. S. Department of Agriculture, Economic Research Service, January 2009.

Markowitz, S., Nesson, E., and Robinson, J. J. 2019. "The effects of employment on influenza rates," *Economics & Human Biology*, 34, 286-295.

Middleton, J., Reintjes, R., and Lopes, H. 2020. "Meat plants – a new front line in the COVID-19 pandemic," *BM*J, 2020, 370:m2716.

O*NET OnLine (n.d.), National Center for O*NET Development.

Orrenius, P. M., and Zavodny, M. 2009. "Do immigrants work in riskier jobs?," *Demography*, 46(3), 535-551.

Perez, M. 2020. "Meatpacking plants tied to more COVID-19 cases than known before, new business outbreak data shows," *Milwaukee Journal Sentinel*, Milwaukee, Wisconsin.

Sinclair, U. 1906. *The Jungle*. New York: Grosset & Dunlap.

Steinberg, J., Kennedy, E., Basler, C., et. al. 2020. "COVID-19 Outbreak Among Employees at a Meat Processing Facility – South Dakota, March-April 2020," Centers for Disease Control and Prevention, Atlanta, Georgia.

Taylor, C. A., Boulos, C., and Almond, D. 2020. "Livestock plants and COVID-19 transmission." *Proceedings of the National Academy of Sciences*, 117(50), 31706-31715.

Waltenburg, M, Victroff, T, Rose, C, et al. 2020. "Update: COVID-19 Among Workers in Meat and Processing Facilities – United States, April-May 2020," Centers for Disease Control and Prevention, Atlanta, Georgia.

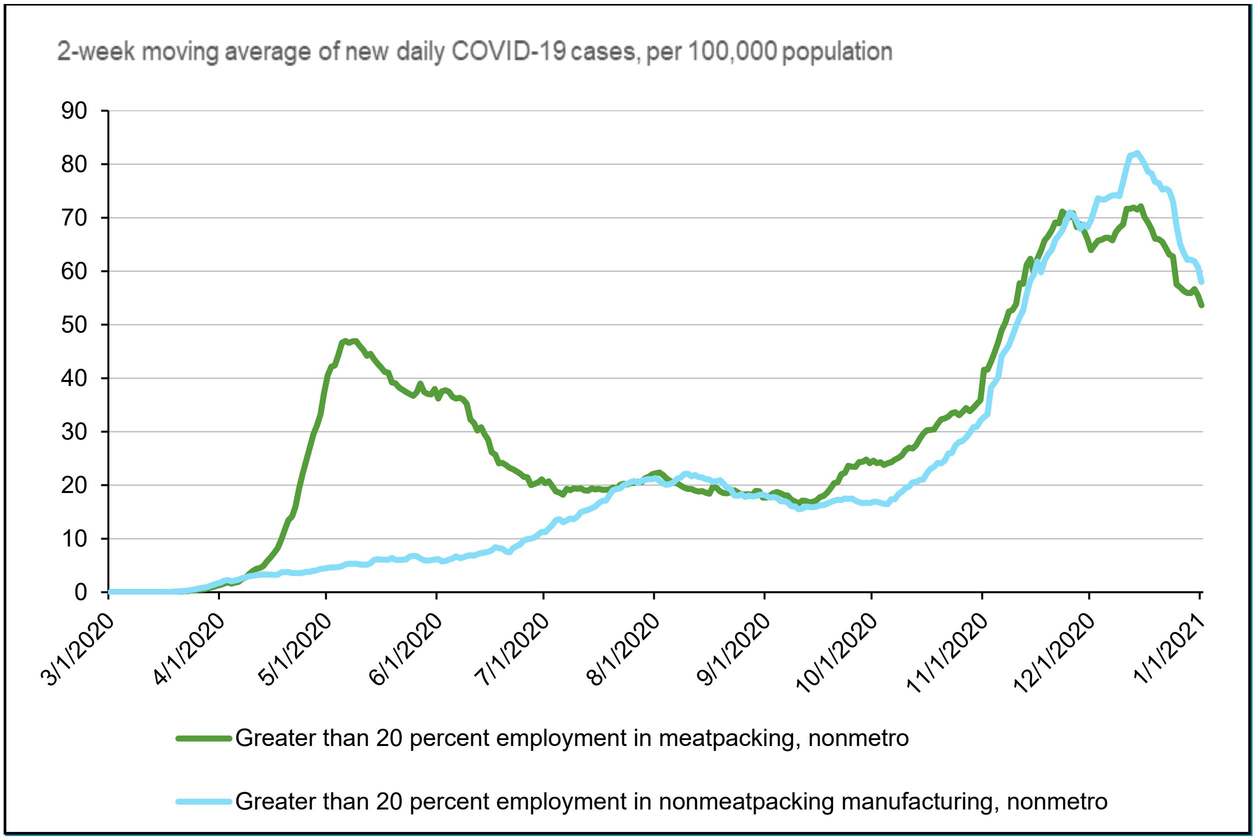
Appendix A: List of 25 highest rates of COVID-19 per 100,000 people for all rural counties in the United States at the end of May 2020

Rank	County	State	Meatpacking-dependent county
1	Colfax	Nebraska	Yes
2	Lake	Tennessee	No
3	Buena Vista	Iowa	Yes
4	Texas	Oklahoma	Yes
5	Nobles	Minnesota	Yes
6	Ford	Kansas	Yes
7	Finney	Kansas	Yes
8	Crawford	Iowa	Yes
9	Saline	Nebraska	Yes
10	Liberty	Florida	No
11	St. Francis	Arkansas	No
12	East Carroll	Louisiana	No
13	Accomack	Virginia	Yes
14	McKinley	New Mexico	No
15	Bullock	Alabama	Yes
16	Galax	Virginia	No
17	Butler	Alabama	No
18	Hancock	Georgia	No
19	Holmes	Mississippi	No
20	Moore	Texas	Yes
21	Wapello	Iowa	No
22	Seward	Kansas	Yes
23	Walker	Texas	No
24	San Juan	Utah	No
25	Dawson	Nebraska	Yes

Note: Hancock, Georgia, is the only county that has a manufacturing dependence other than meatpacking in this list, as more than 20 percent of county employment is in NAICS 3272 Glass and Glass Product Manufacturing.

Sources: USDA, Economic Research Service using data from Johns Hopkins University Coronavirus Resource Center. (n.d.) Center for Systems Science and Engineering, Johns Hopkins University and Medicine, Baltimore, Maryland; Eckert, F., Fort, T. C., Schott, P. K., and Yang, N. J. 2020. Imputing Missing Values in the U.S. Census Bureau's County Business Patterns, No. w26632. National Bureau of Economic Research.

Appendix B: New COVID-19 cases since March 1, 2020: Comparing U.S. counties with 20 percent or more of employment in meatpacking to counties with 20 percent or more of employment in another single non-meatpacking manufacturing industry



Source: USDA, Economic Research Service using data from Johns Hopkins University Coronavirus Resource Center. (n.d.) Center for Systems Science and Engineering, Johns Hopkins University and Medicine, Baltimore, Maryland.