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EDITED BY
Samuel Ayofemi Olalekan Adeyeye,
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REVIEWED BY
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Federal University of Agriculture,
Abeokuta, Nigeria
Emmanuel Amagu Echiegu,
University of Nigeria, Nsukka, Nigeria

*CORRESPONDENCE
Tina L. Saitone
saitone@primal.ucdavis.edu

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Leveraging meatpacking ownership concentration and community centrality to improve disease resiliency

Tina L. Saitone[1]*, K. Aleks Schaefer[2] and Daniel P. Scheitrum[3]

[1]Department of Agricultural and Resource Economics, University of California, Davis, Davis, CA, United States, [2]Department of Agricultural Economics, Oklahoma State University, Stillwater, OK, United States, [3]Department of Agribusiness, California Polytechnic State University, San Luis Obispo, CA, United States

The U.S. meat processing sector has been subject to amplified scrutiny after workers exhibited disproportionately high rates of COVID-19 infections and deaths. In response, Tyson Foods—one of the largest meat packers in the country—mandated that its employees be vaccinated against COVID-19 by November 1, 2021. In this paper, we investigate the impact that the Tyson vaccine mandate had on vaccine uptake, infection rates, and deaths in counties where Tyson processing facilities are located. We find that the mandate resulted in approximately 35,000 additional vaccinations. The resultant vaccine uptake avoided 98 COVID-19 infections per day and nearly 75 COVID-19-related deaths; the associated public health savings total $45.4 million. Employee health-related interventions at the corporate level can leverage industry ownership concentration and the centrality of packing operations in host communities to improve health outcomes and disease resiliency well beyond the packing operations.

KEYWORDS

meatpacking, industry concentration, community centrality, disease resilience, vaccine mandate

1. Introduction

Critics of the United States' industrialized food system have cited the COVID-19 pandemic as the shock that exposed a vulnerable and unstable supply chain (Hendrickson, 2020; Carrillo and Ipsen, 2021). The meat processing industry became the subject of amplified scrutiny and ridicule when employee populations exhibited disproportionately high rates of COVID-19 infections and deaths (Taylor et al., 2020; Saitone et al., 2021).[1] In response, public policies have been proposed in the name of improved meat supply chain resiliency. One such policy, that has gained significant traction, entails government subsidization of small- and medium- sized meatpacking operations (Lusk et al., 2021).

1 Investigations and criticism continues to date surrounding the sector's actions to address outbreaks and whether or not adequate protections for employees were provided (Select Subcommittee, 2021).

Examples include the U.S. Department of Agriculture's (USDA) Meat and Poultry Inspection Readiness Grant Program that has awarded $32 million in grants to local and regional meat and poultry slaughter facilities to support expansion of capacity and improved efficiency and $500 million of American Rescue Plan funds allocated to expand meat and poultry processing capacity (Fatka, 2021; USDA, 2021b). However, policies that compromise the cost savings achieved *via* economies of scale (i.e., an entity's ability to spread costs over larger throughput), create a situation where scale and efficiency are sacrificed in order to recreate a smaller, more geographically dispersed meat processing sector and *possibly* improve disease-transmission resiliency (Ma and Lusk, 2021; Saitone et al., 2021). In this research, we consider an alternative strategy to these policy interventions—leveraging current meatpacking ownership concentration and the centrality of these large industrial employers in host communities to improve community-level health outcomes *via* employer-mandated health interventions.

The U.S. meatpacking industry is horizontally concentrated with just a few firms owning the vast majority of processing facilities (Wohlgenant, 2013). Some of the largest corporate owners (e.g., JBS USA, Smithfield Foods, and Tyson Foods, Inc.) have operations in multiple species-specific supply chains; for example, Tyson Foods is the second-largest meat packer in the world, produces 20% of all meat consumed in the U.S., and is the largest chicken supplier, second-largest beef supplier, and third-largest pork supplier in the country (Tyson, 2021). Large beef and pork processing operations are geographically concentrated in the Midwest and Great Plains, while broiler processing operations are principally located in the South (Figure 1). There are 56 counties in the United States where meatpacking operations account for more than 20 percent of all county-level employment, meatpacking operations are 4 times more likely to dominate county-level employment opportunities than any other manufacturing industry (USDA, 2021a).[2] High employment concentration, coupled with a host of social, demographic, and environmental factors, has solidified the community centrality of these operations, especially in rural areas of the country. Taylor et al. (2020) confirmed that COVID-19 transmission extended well beyond the confines of meat processing operations; one COVID-19 infected worker spread the disease to between 7 and 8 others in the community (i.e., non-meatpacking workers).

The meatpacking industry in aggregate employs approximately 525,000 people (Waltenburg, 2020); 30 percent of all food and beverage manufacturing employees (USDA, 2018). The workforce is primarily comprised of ethnic minorities, many of whom are foreign-born and live below the poverty line with no health insurance (Fremstad et al., 2020). Immigrant workers, particularly those who are less skilled and lack education, are less able to seek alternative options for employment and have substantially less bargaining power and ability to organize or unionize. Immigrant populations are also more likely to keep working despite illness and infection risks given they may not be able to access unemployment benefits or economic safety net measures. Workforce demographics, coupled with the documented racial and income disparities in COVID-19 related health outcomes and vaccine hesitancy, add an additional layer of complexity to the health and worker safety-related issues experienced in the meatpacking industry to date and need to be considered in the future (Waltenburg, 2020).

In August 2021, Tyson Foods mandated that its 120,000 U.S. employees be vaccinated against COVID-19 by November 1, 2021 (Hirsch and Corkery, 2021). This action made Tyson Foods the largest U.S. food company to require COVID-19 vaccinations for its entire workforce (King, 2021).[3] This unilateral action on the part of one of the largest meat processors, with packing operations spanning all three species in the meat supply chain, allows us to determine if industry concentration and the centrality of meat packing operations in host communities, which has perpetuated decades of scrutiny and concern, could be an effective means by which to achieve improved employee and community health outcomes while improving disease transmission resiliency, on a large scale. More specifically, in this work, we measure COVID-19 vaccine uptake, infection rates, and deaths in counties where Tyson processing facilities are located, relative to counties with other large meatpacking plants and non-meatpacking counties, in order to quantify the community-level impacts associated with Tyson Food's vaccine mandate.

To do so, we construct a dataset that matches daily county-level data on vaccine uptake from the U.S. Centers for Disease Control (CDC, 2021a) with daily county-level COVID-19 cases and deaths from USAFACTS (2020) and information from USDA Food Safety Inspection Service (FSIS, 2020) on the location of major beef, pork, and chicken processing plants owned by Tyson Foods (and, thus, subject to the employee vaccine mandate) and its competitors (Figure 1).

2. Methods

We used a series of statistical regression models to measure the impacts of Tyson Food's employee vaccine mandate on vaccine uptake and COVID-19 morbidity and mortality. Section 2.1 describes the models used to analyze

2 Thirty-four percent of non-metropolitan meatpacking-dependent counties are classified as high-poverty (USDA, 2021a).

3 During the mandate bargaining process, Tyson negotiated support of critical labor unions that represent more than 80 percent of their unionized employees. This process resulted in Tyson employees receiving 20 h of paid sick leave; the first national agreement for meatpacking workers to have any type of paid sick leave in history (Polanesk, 2021).

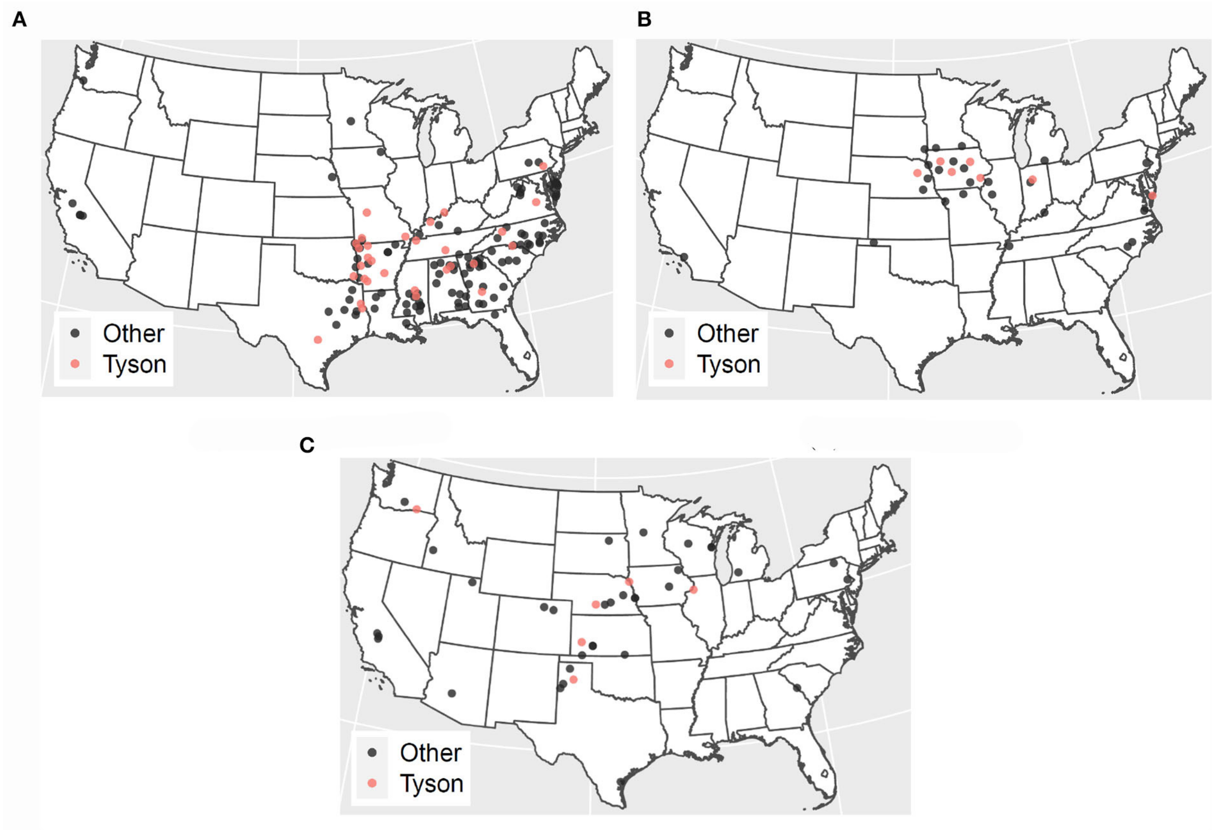

FIGURE 1
Tyson and Non-Tyson Meatpacking locations. Figure shows the location of major Tyson and non-Tyson chicken **(A)**, pork **(B)**, and beef **(C)** processing plants from USDA Food Safety Inspection Service (FSIS, 2020). These data include kill plants (i.e., processing plants that slaughter animals) and not plants that are solely responsible for further processing.

the impacts on vaccine uptake using alternative specifications based on previous literature. Section 2.2 explains the two-way fixed effects model we used to assess how changes in the "stock" of the county vaccinated population affect the "flow" of future county-level COVID-19 infections and deaths. Section 2.3 explains how we combined the analyses from Sections 2.1 and 2.2 to construct counterfactual vaccination levels and disease transmission dynamics. We deduced the aggregate impacts at the national and sectoral levels using these counterfactuals.

2.1. Vaccine uptake model

Difference-in-Difference Design: As a preliminary analysis, we used a difference-in-difference design to compare county-level vaccine uptake rates in Tyson counties (i.e., those that were "treated" with the vaccine mandate) vs. counties with other major packing plants (either beef, pork, or chicken) and non-meatpacking counties. To do so, we estimate the following model:

$$\begin{aligned} V_{i,t} = {} & \rho_0 + \rho_1 Tyson_i + \rho_2 Other_i + \rho_3 Post_t + \rho_4 Post_t \times Tyson_i \\ & + \rho_5 Post_t \times Other_i + \rho_6 \mathbf{X}_i + e_{i,t} \end{aligned} \tag{1}$$

where dependent variable V is alternatively specified as the cumulative percentage of the eligible population in county i that has received a full course of an emergency-authorized COVID-19 vaccine or as the cumulative percentage of the eligible population that have received at least one shot of COVID vaccine. This variable is observed at time t equal to August 3, 2021—the day of the Tyson employee vaccine mandate was announced—and November 1, 2021—the deadline for Tyson employees to be vaccinated.

On the right-hand side of Equation (1), we include variable $Tyson_i$, which is a binary variable that distinguishes between our treatment and control counties. The variable takes value one if there is a Tyson packing plant in the observed county. Otherwise, the variable takes value zero. Similarly, we include variable $Other_i$, which is a binary variable that takes value one if a county includes a non-Tyson packing plant, and is equal to zero otherwise. We also included a indicator variable, "Post," to measure the treatment period. This variable takes value one at time t = November 1, 2021 and value zero at time t = August 3, 2021. The "Post" variable is included independently and interacted with variables $Tyson_i$ and $Other_i$. The impact of the vaccine mandate is measured by coefficient ρ_5—the interaction of the "post" indicator and the "Tyson" indicator.

Vector $\mathbf{X}_i$ includes a series of county-level sociodemographic variables that have been shown to be strong correlates for vaccine uptake, vaccine hesitancy, and vaccine skepticism (Robertson et al., 2021b), including state fixed effects, population density, percent of population over 65 years of age, percent of population white (non-Hispanic), percent black (non-Hispanic), percent Hispanic, percent with at least a college education, unemployment rate, per capita income, percent with less than a high school education, and percent foreign-born.

Impact Dynamics: Next, we measure the impacts of Tyson Food's employee vaccine mandate on county-level vaccine uptake over time using a statistical regression specification based on Robertson et al. (2021a). In a given county i and as of a given date t, the cumulative number of people that has received a full course of an emergency-authorized COVID-19 vaccine (denoted V and expressed as a percentage of the eligible population in the county) is a function of the cumulative number of people vaccinated in periods immediately prior, the current state of disease risks, and the sociodemographic and economic characteristics of the county. These characteristics account for vaccine hesitancy and skepticism among the remaining unvaccinated population and determine the rate at which additional individuals become vaccinated. We also allow—but do not impose—that Tyson Food's employee vaccine mandate induced some fraction of the remaining unvaccinated population to elect for vaccination.

Accordingly, we estimate the following model where

$$\begin{aligned} V_{i,M+n} &= \alpha + \beta_1 V_{i,M-1} + \beta_2 \dot{V}_{i,M-1} + \beta_3 C_{i,M-1} \\ &\quad + \beta_4 \dot{C}_{i,M-1} + \beta_5 \mathbf{Z}_i + \beta_6 Tyson_i + e_{i,M+n} \end{aligned} \tag{2}$$

—as in Equation (1)— the dependent variable V is specified as the cumulative percentage of the eligible population in county i that has received a full course of COVID-19 vaccine or, alternatively, as the share that have received at least one shot of COVID vaccine. In Equation (2), variable V is observed on a given date $M + n$, where date M is August 3, 2021 (the date on which Tyson Foods instituted its employee vaccine mandate) and n is the number of days following the mandate announcement.

Explanatory variable $V_{i,M-1}$ is the cumulative percentage of the eligible population that received a full course of COVID-19 vaccine as of August 3, 2021 (the day of the Tyson mandate was announced). Variable $\dot{V}_{i,M-1}$ is the growth rate in cumulative vaccinations experienced in the county over the 2-week period prior to the mandate announcement ($\dot{V}_{i,M-1} = \frac{V_{i,M-1} - V_{i,M-14}}{V_{i,M-14}}$). Similarly, variable $C_{i,M-1}$ is the cumulative number of COVID-19 cases experienced in the county as of August 3, 2021 (expressed as a share of the county population) and $\dot{C}_{i,M-1}$ is the 2-week growth rate in county COVID-19 case rates.

Consistent with the difference-in-difference analysis in Equation (1), vector $\mathbf{Z}_i$ in Equation (2) includes state fixed effects, population density, percent of population over 65 years of age, percent of population white (non-Hispanic), percent black (non-Hispanic), percent Hispanic, percent with at least a college education, unemployment rate, per capita income, percent with less than a high school education, and percent foreign-born. Also included in vector $\mathbf{Z}_i$ are three dummy variables that indicate whether county i has a large beef packing plant ($Beef_i$), a large pork packing plant ($Pork_i$), or a large chicken processing plant ($Chicken_i$). If one of these types of packing plants is present, the relevant variable takes value one (regardless of whether or not the packing plant is owned by Tyson Foods), otherwise these variables are equal to zero.

In Equation (2), our variable of interest is the binary $Tyson_i$ variable that distinguishes between our treatment and control counties. The coefficient on $Tyson$ (β_6) measures the responsiveness of vaccine uptake n days following the implementation of the Tyson Food employee vaccine mandate. We estimate the model separately for each day n from 1 (August 4, 2021) through 89 (November 1, 2021)—the deadline for the Tyson employee vaccine mandate.[4] This approach allows us to obtain a semi-parametric estimate of the impacts of the mandate on vaccine uptake over time.

Model Robustness—Topographic Regression: We assess the robustness of our results by re-estimating (Equation 2) observed at November 1, 2021 (day 89) using the topographic regression procedure developed by Saitone et al. (2021). According to this procedure, vector $\mathbf{Z}_i$ in Equation (2) is divided into the set of "critical" control variables, which includes state fixed effects and indicators for the presence of a large beef, chicken, or pork packing plant, and "additional" controls, which are sub-divided into five covariate categories: STRUCTURAL$_i$, DEMOGRAPHIC$_i$, ECONOMIC$_i$, EDUCATION$_i$, and HEALTH$_i$.

The model is estimated according to an iterative procedure, where—for a given iteration—we select one variable (or no variables) from a pool of candidate correlates to represent each of the five covariate categories. Consistent with Saitone et al. (2021), the STRUCTURAL category includes 9 candidate correlates, the DEMOGRAPHIC category includes 11 candidate

4 For purposes of the stage-2 regressions described below in Section 2.2, we also estimate (Equation 2) through day 109 (November 21, 2021), which corresponds to 3 weeks following the mandate deadline, since they are not fully and immediately realized at the mandate deadline.

correlates, the ECONOMIC category includes 9 candidate correlates, the EDUCATION category includes 3 candidate correlates, and the HEALTH category includes 12 candidate correlates. Candidate correlates for each of these five categories are reported in Supplementary Table A2. In the next iteration of the procedure, we re-run the model, but change the selected variable for one of the categories. We estimate the model for all combinations of variables within these five covariate categories for a total of 62,400 separate regressions. Then, we make inference based on the peak of the joint probability density for the point estimate and corresponding p-value for coefficient β_6—our variable of interest—across the 62,400 regressions.

2.2. COVID-19 incidence models

After estimating the impacts of Tyson Food's employee vaccine mandate on county-level vaccine uptake in Equation (2), we next determine the extent to which such a change in the "stock" of the county vaccinated population—at this phase of the pandemic—affects the "flow" of future county-level COVID-19 morbidity and mortality rates. To do so, we estimate the following reduced-form panel fixed-effects specifications:

$$C_{i,t} = \gamma_0 + \gamma_1 C_{i,t-7} + \gamma_2 V_{i,t-7} + \gamma_3 \mathbf{R}_i + \epsilon_{i,t} \quad (3)$$

$$D_{i,t} = \lambda_0 + \lambda_1 D_{i,t-7} + \lambda_2 V_{i,t-7} + \lambda_3 \mathbf{R}_i + u_{i,t} \quad (4)$$

Dependent variables C and D in Equations (3) and (4), respectively, represent the cumulative number of COVID-19 cases per capita and deaths per capita experienced in county i as of date t. In these models, case and death rates evolve dynamically according to a 7-day autoregressive lag process. Similarly, current case and death rates in a given county are a function of county vaccination levels (V), which is defined as above in Equation (2). We specify this variable as a 7-day lag to account for the fact that contemporaneous vaccinations are likely subject to reverse causality—as discussed in the context of eqrefeq:uptake, higher contemporaneous case and death rates may encourage unvaccinated individuals to opt for vaccination. Additionally, the lag specification allows us to incorporate the reality that individuals do not achieve immunity until a number of days after inoculation.

Vector $\mathbf{R}_i$ in Equations (3) and (4) includes two-way (i.e., county and date) fixed effects. The date fixed effects account for the fact that COVID case and death rates wax and wane over time for reasons unrelated to changes in vaccination rates. The county fixed effects control for time-invariant differences across counties (such as those socioeconomic and demographic characteristics included in the stage-one regression) that drive local COVID transmission. To assess the sensitivity of our results to alternative specifications, we also estimate (Equations 3, 4) by specifying vector $\mathbf{R}_i$ to include the state fixed effects and the sociodemographic controls included in vector $\mathbf{X}_i$ from Equation (1), rather than county-specific fixed effects.

We estimate models (3) and (4) using a data sample beginning August 4, 2021 and ending November 21, 2021. The start date is chosen to align with the implementation of the Tyson mandate—this accounts for the fact that the epidemiological benefits of a marginal change in vaccination rates evolve over time as the pandemic progresses. Thus, it is important to examine the relationship between vaccinations and COVID-19 incidence only at the contemporaneous time. The sample end date is purposely chosen as 3 weeks after the Tyson mandate deadline—this accounts for the fact that the health benefits of the vaccination scheme may be somewhat delayed and necessarily accrue over time.

2.3. Construction of counterfactuals and impact aggregation

We combine the results from Section 2.1—the effects of Tyson Food's employee vaccine mandate on vaccine uptake—with the results from Section 2.2—the effects of increased vaccination levels on epidemiological dynamics—to deduce the impacts of the mandate on county-level COVID-19 case and death rates. We derive counterfactual vaccination levels ($\hat{V}_i^{CF}$) in Tyson counties in the absence of the mandate on a given date t as $\hat{V}_{i,t}^{CF} = V_{i,t} - \hat{\beta}_{6|t}$, where $\hat{\beta}_{6|t}$ is the estimated coefficient on the Tyson treatment in Equation (2) for day t from August 4, 2021 through November 21, 2021. We then allow counterfactual case ($\hat{C}_i^{CF}$) and death ($\hat{D}_i^{CF}$) rates to evolve dynamically based on counterfactual vaccination levels ($\hat{V}_i^{CF}$) according to estimated parameters $\hat{\gamma}_0, \hat{\gamma}_1, \hat{\gamma}_2$ and $\hat{\gamma}_3$ from Equation (3) and estimated parameters $\hat{\lambda}_0, \hat{\lambda}_1, \hat{\lambda}_2$ and $\hat{\lambda}_3$ from Equation (4).

Finally, we convert county-level vaccination rates to total numbers of vaccinations induced as of November 21, 2021 as $\hat{\beta}_{6|\text{November 21, 2021}} \times \textit{EligiblePopulation}_i$. Similarly, total cases and deaths avoided are assessed as $\left(C_{i|\text{November 21, 2021}} - \hat{C}^{CF}_{i|\text{November 21, 2021}}\right) \times \textit{Population}_i$ and $\left(D_{i|\text{November 21, 2021}} - \hat{D}^{CF}_{i|\text{November 21, 2021}}\right) \times \textit{Population}_i$. This allows us to aggregate impact estimates at the national and sectoral levels. We derive confidence intervals for the above estimates using a Bayesian bootstrapping procedure with 500 re-sampled random draws from the posterior distribution of coefficient estimates of $\hat{\beta}_{6|t}$ from Equation (2).

Consistent with Saitone et al. (2021), we approximate the economic value of the mortality and morbidity savings resulting from the vaccine mandate. For each infection, we assign a "cost" to account for approximately 2 weeks of lost wages (from the perspective of the infected individual) and lost economic productivity (from the perspective of the county). Savings are assessed by multiplying the number of cases avoided by the mandate times the 2-week pro rata equivalent of the annual

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county per capita income. The economic costs of morbidity are assessed as the present value of the annual county per capita income for 20 years, evaluated with a three-percent annual discount rate.

2.4. Data and summary statistics

Our final data set contains a balanced panel with daily information on cumulative vaccinations and cumulative COVID-19 cases and deaths for 2,093 U.S. counties. We observe 32 counties with Tyson plants, including 2 beef processing locations, 5 pork processing locations, and 25 chicken processing locations. We observe a further 95 counties with non-Tyson plants, including 17 beef processing locations, 18 pork processing locations, and 95 chicken processing locations. As of August 3rd, 2021 (the day Tyson Food's employee vaccine mandate was announced) 30.8% of eligible individuals were fully vaccinated (36.9% partially vaccinated) in the median Tyson county (Supplementary Figure A1). Vaccination rates in other (non-Tyson) meatpacking counties were similar. In the median non-Tyson meatpacking county, 31.1% of eligible individuals were fully vaccinated (36.2% partially vaccinated). These rates are lower than vaccine uptake in non-meatpacking counties, where 35.% of eligible individuals were fully vaccinated (40.2% partially vaccinated) at the median. However, as of November 1, 2021, the deadline for Tyson employee vaccination, vaccine uptake in Tyson counties had risen, both relative to other meatpacking and non-meatpacking counties. The median Tyson county had 42.1% of individuals fully vaccinated (49.4% partially vaccinated) as of November 1, 2021, compared to 40.9% fully vaccinated (47.6% partially vaccinated) in other meatpacking counties and 44.1% fully vaccinated (49.6% partially vaccinated) in non-meatpacking counties.

To a lesser extent, similar trends are visible with respect to COVID-19 incidence rates. As of August 3, 2021, the cumulative per capita COVID-19 case rate was approximately 12.4% (per capita COVID-19 death rate 0.20%) in Tyson counties. This is higher (lower) than other meatpacking counties, where the cumulative per capita case (death) rate was 12.1% (0.22%), and non-meatpacking counties, where the cumulative per capita case (death) rate was 10.6% (0.19%). By November 9, 2021—1 week after the employee vaccine deadline—the cumulative per capita case (death) rate in Tyson counties was 16.9% (0.27%) vs. 16.6% (0.28%) in other meatpacking counties and 15.0% (0.25%) in non-meatpacking counties. Within 3 weeks after the deadline (November 21, 2021), cumulative per capita case (death) rates were 17.0% (0.27%), 16.9% (0.28%), and 15.5% (0.26%), respectively, in Tyson counties, other meatpacking counties, and non-meatpacking counties.

Summary statistics for the sociodemographic control variables used to estimate Equations 1 and (2) and the pre-mandate "benchmark" vaccine and COVID-19 incidence rates used in Equation (2) are reported in Supplementary Table A1. County-level GOP vote shares in the 2020 Presidential Election are obtained from the MIT (2021). Data on county-level population density, percent of population over 65 years of age, percent of population white (non-Hispanic), percent black (non-Hispanic), percent Hispanic, percent with at least college education, unemployment rate, per capita income, percent with less than high school education, and percent foreign-born are from the Economic Research Service "Atlas of Rural and Small-Town America" (ERS, 2020). Summary statistics for the full set of candidate correlates used in the topographic regression analysis are reported in Supplementary Table A2. These data were obtained from ERS (2020) and the Robert Wood Johnson Foundation "County Health Rankings" (RWJ Foundation, 2020).

3. Results

Figure 2 summarizes the impacts of Tyson Food's employee vaccine mandate on county-level vaccination rates. Figure 2A reports the results of a difference-in-difference comparison between Tyson, other meatpacking, and non-meatpacking counties evaluated on the date the mandate was announced (August 3, 2021) and at the mandate deadline (November 1, 2021). This analysis suggests that the Tyson employee vaccine mandate increased local vaccine uptake by 2.1 ± 1.9% for full vaccination (2.2 ± 2.0% for partial vaccination).[5] As of August 3, 2021, after controlling for time-invariant factors at the state level and a variety of county-level socio-demographic factors, Tyson counties had an average uptake of 50.1 ± 14.7% of the eligible population for full vaccination (62.7 ± 16.5% for partial vaccination), compared to 50.2 ± 14.8% (62.6 ± 16.7% for partial vaccination) in other large meatpacking counties, and 51.6 ± 15.1% (64.1 ± 17.0% for partial vaccination) in non-meatpacking counties. By November 1, 2021, the equivalent estimate was 60.8 ± 14.2% (74.5 ± 16.0%) for Tyson counties vs. 59.6 ± 14.3% (73.3 ± 16.1%) for other large meatpacking counties and 60.1 ± 14.4% (73.7 ± 16.3%) in non-meatpacking counties. As a result of the vaccine mandate, vaccinations in Tyson counties were higher than rates in both types of comparator counties.

Figure 2B summarizes the impacts of the mandate on vaccine uptake over time. These estimates—which form the basis of the impacts on incidence in Figure 3—are more conservative

5 Full vaccination is defined by the CDC as having received 2 doses of the Pfizer vaccine, 2 doses of the Moderna vaccine, or 1 dose of the Johnson and Johnson vaccine. Partial vaccination is defined as having received a single dose of either the Pfizer or Moderna vaccine.

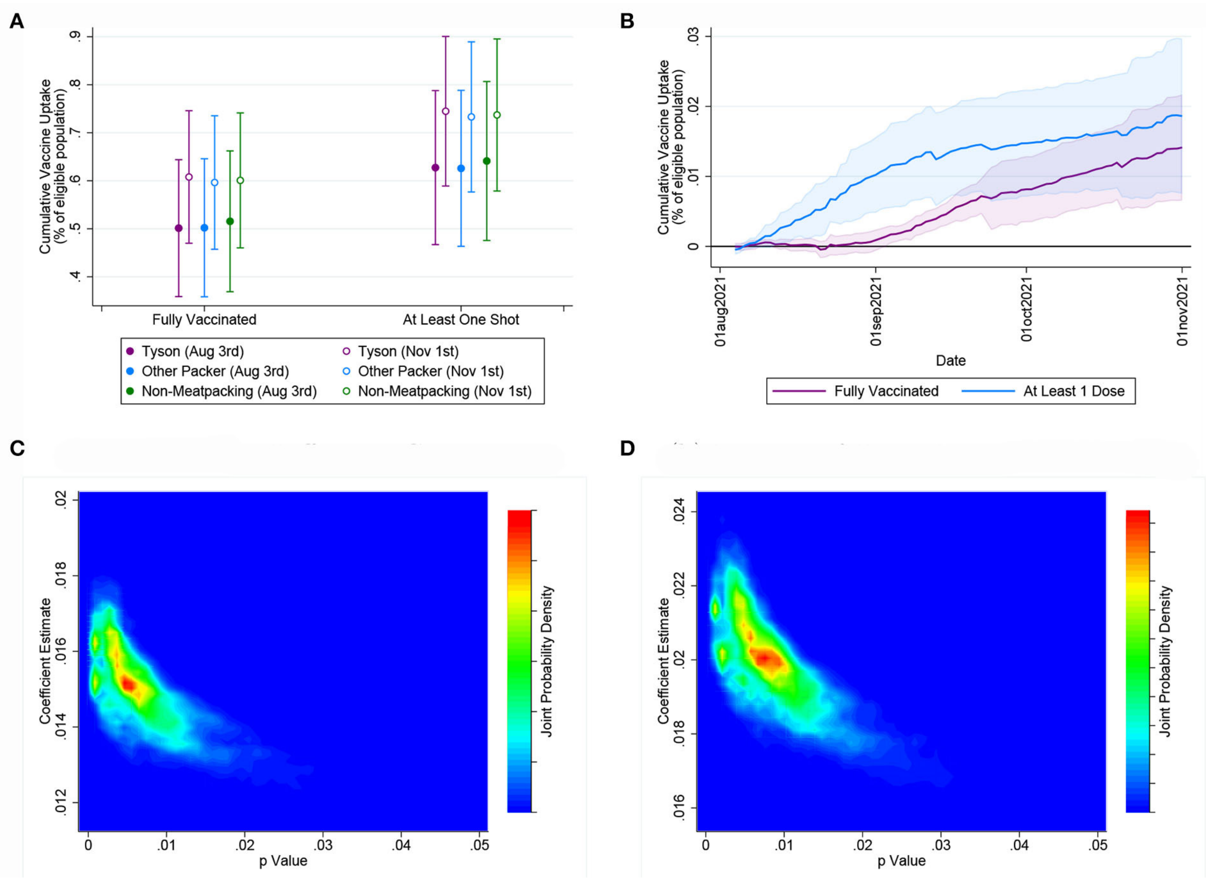

FIGURE 2
Impacts of Tyson Food's employee mandate on county-level vaccine uptake. Figure summarizes the impacts of Tyson Food's employee vaccine mandate on county-level vaccination rates. **(A)** reports the results of a difference-in-difference comparison between Tyson, other meatpacking, and non-meatpacking counties evaluated on the date the mandate was announced (August 3, 2021) and at of the mandate deadline (November 1, 2021). **(B)** of the Figure summarizes the impacts of the mandate on vaccine uptake over time. **(C,D)** investigate the robustness of our main results using a topographic regression model (Saitone et al., 2021).

than the difference-in-difference analysis. According to this analysis, by November 1st, the Tyson employee vaccine mandate increased local uptake by 1.4 ± 0.8% for full vaccination (1.9 ± 1.1% for partial vaccination). The estimated time dynamics of the impacts shown in Figure 2B are consistent with the Pfizer and Moderna Covid-19 immunization schedules. The major growth in partial vaccinations attributable to the Tyson mandate came predominantly in late August and early September 2021, whereas the growth in full vaccinations attributable to the Tyson mandate came 3–4 weeks later in late September and early October. This is consistent with the CDC-recommended interval between the first and second dose for Pfizer (21 days) and Moderna (28 days) (CDC, 2021b).

Figures 2C,D investigate the robustness of our main results using a topographic regression model indicating statistically significant positive impacts over tens of thousands of alternate model specifications (Saitone et al., 2021). Results from these models are consistent with the analyses in Figures 2A,B. Evaluated at the mandate deadline, the topographic peak estimate suggests the mandate increased local rates of full vaccination by 1.5% in Tyson counties ($p = 0.005$) and 2.0% for partial vaccination ($p = 0.008$) in counties with Tyson meat processing plants.

Figure 3 summarizes the impacts of Tyson's employee vaccine mandate on county-level COVID-19 incidence from August 4, 2021 through November 21, 2021. Figure 3A shows the impacts on COVID-19 case rates over time. Our COVID-19 incidence models suggest that—within 1 week—a one-percentage-point increase in the share of the vaccine-eligible population who have been fully vaccinated against COVID-19 is associated with a 0.8 ± 0.03 percentage-point reduction in the per capita COVID-19 case rate (Supplementary Table A3). Combining these estimates with our vaccine uptake estimates, we find that—by November 21, 2021 (3 weeks after the Tyson-imposed vaccination deadline)—the mandate had avoided the equivalent of 4.3 ± 1.2 COVID-19 cases per 10,000 residents

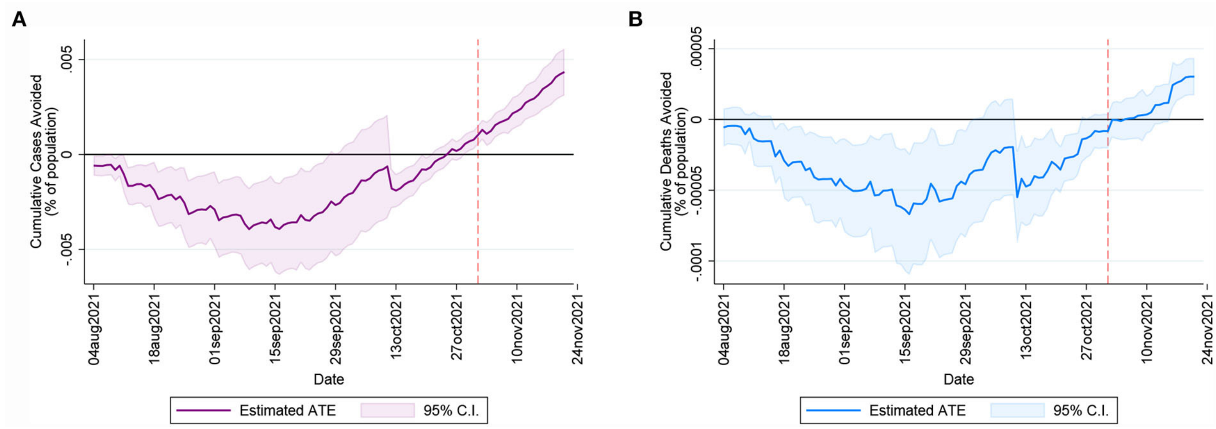

FIGURE 3
Impacts on Tyson Food's employee mandate on county-level COVID-19 incidence. Figure summarizes the impacts of Tyson's employee vaccine mandate on county-level COVID-19 incidence from August 4, 2021 through November 21, 2021. **(A)** shows the impacts on COVID-19 case rates over time, and **(B)** shows the impacts on COVID-19 death rates.

in Tyson counties. Figure 3B shows the impacts of the Tyson vaccine mandate on local COVID-19 death rates. Our COVID-19 incidence models suggest a one-percentage-point increase in the share of fully vaccinated people reduces COVID-19 deaths by a rate of 0.8 ± 0.4 per 100,000 residents (Supplementary Table A3). Thus, by November 21, 2021, the mandate had avoided the equivalent of 3.0 ± 1.3 COVID-19 deaths per 100,000 residents in Tyson counties.

We aggregate across counties to derive the total number of vaccinations induced by the Tyson employee vaccine mandate and the corresponding number of COVID-19 cases and deaths avoided. In total, Tyson's mandate resulted in 34,844 ± 5,920 additional full vaccinations (45,856 ± 8,062 partial vaccinations). Evaluated as of 3 weeks following the mandate deadline, these disease prevention efforts resulted in a total of 75 ± 32 deaths avoided and a daily reduction of 98 ± 65 in COVID-19 cases. The public health value of this disease avoidance equates to approximately $45.4 million saved. Figures 4A,B distill these estimates based on species processed at Tyson meat packing facilities. The largest COVID-19-disease-related savings were generated in chicken processing counties, where Tyson's mandate induced 29,636 ± 5,715 additional full vaccine courses, saving a total of 63 ± 28 lives and generating approximately $38.3 million in public health savings.

4. Discussion

Antecedent literature has documented that meat packing operations exhibited disproportionately high rates of COVID-19 infections and deaths. Taylor et al. (2020) estimated that 6 to 8 percent of all infections and 3 to 4 percent of all deaths in the U.S. were attributable to meatpacking operations in the early stages of the pandemic. Recently, the Select Subcommittee on the Coronavirus Crisis concluded that infections and deaths among the top five meat packers were almost 3 times larger than originally reported; 59,000 COVID-19 infections and 269 COVID-related deaths during the first year of the pandemic (Select Subcommittee, 2021). Collectively the evidence gathered suggests that meatpacking operations have the potential to generate substantial negative health-related externalities for host communities. Yet, to date researchers have failed to consider the possibility that these horizontally concentrated, large-scale employers have the ability to enact policies that have health-related benefits for employees and the communities of which they are a part. Herein, we investigate the impact that the Tyson COVID-19 vaccine mandate had on vaccine uptake, infection rates, and deaths in counties where Tyson processing facilities are located. We find that the mandate resulted in approximately 35,000 additional vaccinations across the U.S. This increased vaccine uptake avoided thousands of COVID-19 infections and almost 75 COVID-19 deaths with an associated public health savings of approximately $45.4 million.

The impacts derived in this study are conservative estimates of the true impact of Tyson's vaccine mandate; the "control" counties that act as a baseline in the analysis (i.e., both non-Tyson meatpacking counties or non-meatpacking counties) have all been engaged in ongoing efforts, public and private, to increase COVID-19 vaccine uptake. For example, JBS engaged in a campaign to administer on-site vaccinations and has launched a pilot program requiring employee vaccinations for on-boarding at certain facilities; in some JBS plants, employee vaccination rates are as high as 92 percent (Select Subcommittee, 2021). In addition, previous work considering the impacts of COVID-19 on meatpacking operations documents that there are substantial spillover (i.e., beyond county boundaries) impacts (Taylor et al., 2020; Saitone et al., 2021). Because our modeling approach uses county-level boundaries to estimate average

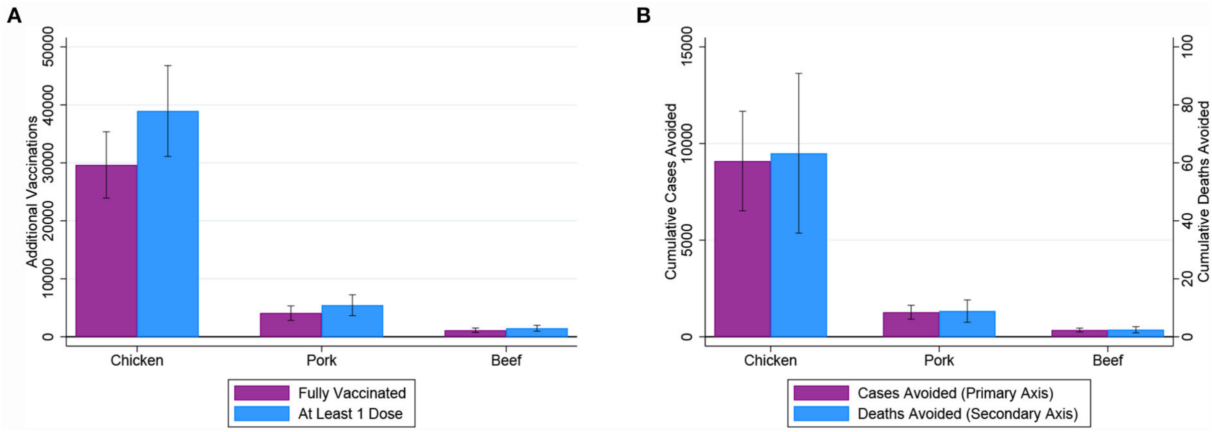

FIGURE 4
Impacts on national vaccine uptake and COVID-19 incidence. Figure shows the total number of vaccinations induced by the Tyson employee vaccine mandate and the corresponding number of COVID-19 cases and deaths avoided, broken down by Tyson plant type. Count values for chicken plants exceed those of pork or beef plants because Tyson operates many more chicken facilities than the other meat types. **(A)** Vaccinations by plant type. **(B)** COVID-19 incidence by plant type.

treatment effects, the methodology does not account for cross-county spillovers that create positive externalities.

Amid growing concerns that voluntary vaccination rates and incentive-based approaches will be insufficient to curtail COVID-19 transmission, vaccine mandates have been suggested as the most feasible and effective policy available (Mulligan and Harris, 2021). However, widespread implementation of employer-mandated vaccination will not come without significant impediments including limited public acceptance (Largent et al., 2020), potential mass employee resignations (Rothstein et al., 2021), possible legal ramifications for employers, and the ongoing introduction of bills by state legislatures to prohibit employer mandates all together (Marr, 2020). As policymakers, industry leaders, and employers throughout the food supply chain grapple with how to preserve the existing, cost-efficient supply chain while also improving the health and welfare of a vulnerable employee population, evidence surrounding the potential benefits associated with employer-mandated vaccinations is particularly valuable. Yet, these impacts may not be possible in other settings where food manufacturing operations are not central to the host community or where horizontal concentration is absent. While this analysis presents the opportunity to explore the possibilities associated with large-scale corporate mandates where employees have limited outside options, there will surely be differences in the magnitude of impacts across corporate ownership structures, operational characteristics, labor conditions, and geography that will require further study.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.989876/full#supplementary-material

References

Carrillo, I. R., and Ipsen, A. (2021). Worksites as sacrifice zones: structural precarity and COVID-19 in us meatpacking. *Sociol. Perspect.* 64, 726–746. doi: 10.1177/07311214211012025

CDC (2021a). *COVID-19 Vaccinations in the United States, County*. Available online at: https://data.cdc.gov/Vaccinations/COVID-19-Vaccinations-in-the-United-States-County/8xkx-amqh?fbclid=IwAR2MedNjnGoPoa5Ai8oQAcZ4RNNc4oedfTsvF2JLzPvo0-Z5-UUvFZ826mw

CDC (2021b). *Different COVID-19 vaccines*. Centers for Disease Control and Prevention Website. Available online at: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines.html

ERS (2020). *Atlas of Rural and Small-Town America*. Available online at: https://www.ers.usda.gov/data-products/atlas-of-rural-and-small-town-america/#::text=The%20Atlas%20of%20Rural%20and,household%20size%2C%20and%20family%20composition

Fatka, J. (2021). *Usda Invests in Strengthening Meat Supply Chain*. Beef Magazine. Available online at: https://www.beefmagazine.com/beef/usda-invests-strengthening-meat-supply-chain

Fremstad, S., Rho, H. J., and Brown, H. (2020). *Meatpacking Workers Are a Diverse Group Who Need Better Protections*. Washington, DC: Center for Economic and Policy Research. Available online at: https://cepr.net/meatpacking-workers-are-a-diverse-group-who-need-better-protections/

FSIS (2020). *Meat, Poultry, and Egg Product Inspection Directory*. Available online at: https://origin-www.fsis.usda.gov/wps/portal/fsis/topics/inspection/mpi-directory

Hendrickson, M. K. (2020). Covid lays bare the brittleness of a concentrated and consolidated food system. *Agric. Human Values.* 37, 579–580. doi: 10.1007/s10460-020-10092-y

Hirsch, L., and Corkery, M. (2021). How tyson foods got 60,500 workers to get the coronavirus vaccine quickly. *New York Times*. Available online at: https://www.nytimes.com/2021/11/04/business/tyson-vaccine-mandate.html

King, D. (2021). *Our Next Step in the Fight Against the Pandemic*. Tyson Foods. Available online at: https://thefeed.blog/2021/08/03/our-next-step-in-the-fight-against-the-pandemic/

Largent, E. A., Persad, G., Sangenito, S., Glickman, A., Boyle, C., and Emanuel, E. J. (2020). Us public attitudes toward COVID-19 vaccine mandates. *JAMA Network Open.* 3, e2033324–e2033324. doi: 10.1001/jamanetworkopen.2020.33324

Lusk, J. L., Tonsor, G. T., and Schulz, L. L. (2021). Beef and pork marketing margins and price spreads during COVID-19. *Appl. Econ. Perspect. Policy.* 43, 4–23. doi: 10.1002/aepp.13101

Ma, M., and Lusk, J. L. (2021). *Concentration and Resiliency in the us Meat Supply Chains*. Working Paper. Available online at: https://static1.squarespace.com/static/502c267524aca01df475f9ec/t/604a8fd90c5f442753fc6b2d/1615499225493/Ma%2BLusk_Concentration_resiliency_US_meat_supply_20210310.pdf

Marr, C. (2020). *Workplace COVID-19 Vaccine Mandates Targeted by State Lawmakers*. Bloomberg Law. Available online at: https://news.bloomberglaw.com/daily-labor-report/workplace-covid-19-vaccine-mandates-targeted-by-state-lawmakers

MIT (2021). *MIT Election Data Science Lab*. Available online at: https://electionlab.mit.edu/data

Mulligan, K., and Harris, J. E. (2021). COVID-19 vaccination mandates for school and work are sound public policy. *White Paper*. Los Angeles, CA: University of Southern California.

Polanesk, T. (2021). *Tyson Foods, Unions Strike Deal Over COVID-19 Vaccine Mandate*. Reuters, Available online at: https://www.reuters.com/legal/government/tyson-foods-meatpacking-union-strike-deal-over-vaccine-mandate-2021-09-03/

Robertson, C., Schaefer, K. A., and Scheitrum, D. (2021a). Are vaccine lotteries worth the money? *Econ. Lett.* 209, 110097. doi: 10.1016/j.econlet.2021.110097

Robertson, C., Scheitrum, D., Schaefer, A., Malone, T., McFadden, B. R., Messer, K. D., et al. (2021b). Paying americans to take the vaccine–would it help or backfire? *J. Law Biosci.* 8, lsab027. doi: 10.1093/jlb/lsab027

Rothstein, M. A., Parmet, W. E., and Reiss, D. R. (2021). Employer-mandated vaccination for COVID-19. *Am. J. Public Health* 111, 1061–1064. doi: 10.2105/AJPH.2020.306166

RWJ Foundation (2020). *County Health Rankings*. Available online at: https://www.countyhealthrankings.org/explore-health-rankings/rankings-data-documentation

Saitone, T. L., Schaefer, K. A., and Scheitrum, D. P. (2021). COVID-19 morbidity and mortality in us meatpacking counties. *Food Policy* 101, 102072. doi: 10.1016/j.foodpol.2021.102072

Select Subcommittee (2021). "How the meatpacking industry failed the workers who feed America," in *Hearing of the House Oversight and Reform Select Subcommittee on the Coronavirus Crisis, 117th Congress (2021-2022)*. Available online at: https://www.congress.gov/event/117th-congress/house-event/114179

Taylor, C. A., Boulos, C., and Almond, D. (2020). Livestock plants and COVID-19 transmission. *Proc. Natl. Acad. Sci. U.S.A.* 117, 31706–31715. doi: 10.1073/pnas.2010115117

Tyson (2021). *Tyson Food Facts*. Tyson Website. Available online at: https://ir.tyson.com/about-tyson/facts/default.aspx

USAFACTS (2020). *Coronavirus Locations: COVID-19 Map by County and State*. Available online at: https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/

USDA (2018). *Food and Beverage Manufacturing Employees by Industry*. Available online at: https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58286

USDA (2021a). *The Meatpacking Industry in Rural America During the COVID-19 Pandemic*. Available online at: https://www.ers.usda.gov/covid-19/rural-america/meatpacking-industry/

USDA (2021b). *Usda Announces 500 Million for Expanded Meat and Poultry Processing Capacity as Part of Efforts to Increase Competition, Level the Playing Field for Family Farmers and Ranchers, and Build a Better Food System*. Available online at: https://www.ers.usda.gov/covid-19/rural-america/meatpacking-industry

Waltenburg, M. E. A. (2020). Update: COVID-19 among workers in meat and poultry processing facilities-united states, April-May 2020. *Mob. Mortal. Weely Rep.* 69, 887–892. doi: 10.15585/mmwr.mm6927e2

Wohlgenant, M. K. (2013). Competition in the us meatpacking industry. *Ann. Rev. Resour. Econ.* 5, 1–12. doi: 10.1146/annurev-resource-091912-151807