Seasonal Farm Labor and Risk of COVID-19 Spread

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Abstract

An inward shock to farm labor supply during a critical season in agricultural production could be devastating to production. The COVID-19 pandemic in 2020 caused unprecedented shocks to agricultural food systems, including increased labor-related costs and uncertainty, and despite employer precautions, there were numerous worksite outbreaks of COVID-19. This paper examines the relationship between month-to-month variation in historical agricultural employment and changes in the incidence of confirmed COVID-19 cases and deaths within U.S. counties from April-August 2020. The results show that employment of 100 additional workers in fruit, vegetable, and horticultural (FVH) production in 2019 was associated with a 4.5% increase in COVID-19 cases within counties in 2020 or and additional 25.17 COVID-19 cases and 0.48 COVID-19 deaths per 100,000 individuals in the 2019 monthly county workforce. If the costs of implementing health and safety measures for seasonal workers is sufficiently high, agricultural producers may seek out alternative labor-saving technologies to reduce labor costs and input uncertainty.

Farm labor demand is often seasonal and uncertain, particularly in high value crops such as fruits and vegetables that are still harvested by hand. In January 2021, the American Farm Bureau Federation president Zippy Duvall stated that "the biggest limiting factor of American agriculture is our labor force" (Harker, 2021), thus underscoring the importance to industry leaders and policymakers of understanding how major shocks like COVID-19 affect farm labor cost and uncertainty. In this paper, I measure the association between historical monthly agricultural employment in 2019 and the incidence of new COVID-19 cases and deaths within U.S. counties from April-August 2020. The findings from this paper can help inform which agricultural industries were most exposed to coronavirus-related risks in worker health and labor supply in 2020 and determine priority strategies for managing shocks to labor costs and threat of disruptions to labor supply.

Worker safety during the coronavirus pandemic was, and still is, of primary concern, particularly in essential industries where working remotely is not possible. Despite employer precautions, there were numerous worksite outbreaks of COVID-19 in 2020 (Dorning and Skerritt, 2020; Reiley, 2020). The insights from this paper can help producers and policymakers anticipate vulnerabilities in the food supply chain due to worker exposure to heightened health risks and uncertainty in labor supply. As stated in a 2020 Congressional report, "If labor shortages become severe, they could lead to wider multi-state, and possible national, food shortages of affected products" (Congressional Research Service, May 8, 2020). While no such food shortage materialized in the United States in 2020, health experts warn that the threat of severe outbreaks is not yet over (Stein, 2021). Understanding which commodities or agricultural activities are most highly associated with COVID-19 spread can help producers and managers throughout the food supply chain prepare for and mitigate losses and future risk. Some producers may look to technological advances, including mechanical harvesters and robots to reduce labor costs, risk, and uncertainty.

Despite recent efforts to quickly distribute vaccines to farm workers, much is still unknown about how COVID-19 mutates or the long-term efficacy of new vaccines to

protect individuals from the virus, and many farm workers say that they do not plan to get vaccinated (UC Berkeley School of Public Health, 2020). Thus, even as vaccines become available, coronavirus-related health risks are still of critical importance in food production industries. Yakima County, Washington, one of the primary counties for fruit and vegetable production, had the highest rate of COVID-19 infection on the West Coast in June 2020 (Dorning and Skerritt, 2020), and 900 cases of COVID-19 were reported in Immokalee, Florida between April and June 2020 (Reiley, 2020). Since many farm workers follow the harvest of crops, such as from Immokalee up the Eastern shore, one might be concerned that follow-the-crop workers could rapidly spread COVID-19 from one agricultural community to another.

This paper measures the relationship between variation in historical monthly employment in the fruit, vegetable, and horticultural (FVH) sectors from April-August 2019 and new COVID-19 cases and deaths within U.S. counties in 2020. I limit the months of analysis to April-August since university reopenings might have influenced COVID-19 growth in the fall and potentially correlated with changes in farm employment. COVID-19 data come from the *New York Times* database, and agricultural employment data are taken from the Quarterly Census of Employment and Wages (QCEW). The QCEW records employment by industry at the county-month level, and COVID-19 had no bearing on employment decisions in years prior to 2020. Controls for state-by-month fixed effects account for changes in state mandates and attitudes with respect to social distancing, quarantine, and masks, along with other unobserved state-level temporal changes in COVID-19 growth and susceptibility. I repeat the analysis using more disaggregated crop industry groupings and non-FVH crop and livestock industries as explanatory variables. I also perform several robustness checks, including controls for 2019 employment in other seasonal industries, limiting the sample to rural counties,[1], and dropping all counties with employment in the meat processing sector where worksite outbreaks of COVID-19 were relatively common in 2020.

[1]Rural classification is based on the Office of Management and Budget (OMB) 2013 Urban Influence Codes, and I include only non-metropolitan counties in the robustness check.

The findings show that employment of 100 additional workers in the FVH sector in 2019 was associated with a 4.5% increase in COVID-19 cases within counties or an additional 25.17 COVID-19 cases per 100,000 individuals in the 2019 monthly workforce and 0.48 additional COVID-19 deaths per 100,000. Results are robust to the inclusion of controls for 2019 monthly employment in post-harvest crop activities, construction, retail, and accommodations and food industries. Further analysis of the relation between specific crop employment and incidence of COVID-19 within counties shows a significant positive increase in COVID-19 cases or deaths associated with employment by berry and other fruit producers, vegetable and melon producers, greenhouses, and Farm Labor Contractors (FLCs). I find no such statistically significant association between COVID-19 cases or deaths and employment in more mechanized crops, including grains, oilseeds, and field crops, or in livestock. The findings suggest that FVH crops, which frequently depend on a large seasonal workforce, are more susceptible to COVID-related labor supply disruptions. Thus FVH producers likely incurred higher costs related to worker health provisions or risk management strategies intended to reduce the exposure to COVID-19 or the probability of a labor shortage.

This paper contributes to the literature on tightening U.S. farm labor supply and increasing labor costs along with the emerging literature examining how social activity and migration influence the spread of COVID-19. Richards (2018) shows evidence of persistent farm labor shortages in sub-sectors of the California farm labor market. Inward farm labor supply shocks due to changes in immigration enforcement policies have led to increased farm wages and reduced agricultural producer profitability (Ifft and Jodlowski, 2016; Kostandini, Mykerezi, and Escalante, 2014), substitution of capital for labor (Charlton and Kostandini, 2020; Clemens, Lewis, and Postel, 2018), and increased supply of family farm labor (Luo, Kostandini, and Jordan, 2018). The coronavirus pandemic in 2020 differs from previous shocks to labor supply in that the pandemic is likely temporary. However, in an era of tightening farm labor supply as the U.S. is currently experiencing, even temporary increases in labor costs and uncertainty of labor supply could push producers to invest in more mechanized methods of production.

This paper also contributes to new literature examining factors that increase the spread of COVID-19 (Dave et al., 2020a,b; Friedson et al., 2020; Mangrum and Niekamp, 2020). However, unlike much of the COVID literature, this paper does not attempt to identify the mechanisms through which labor-intensive agricultural activities lead to increased incidence of COVID-19 within counties. Rather, the objective of this paper is to identify which crops experienced the greatest increase in exposure to COVID-19 during labor-intensive periods of production in 2020. The findings can help inform producers and policymakers how to appropriately respond to the associated risks born by farm workers and agricultural producers.

Farm Labor Background

Farm labor shortages have been a primary concern to U.S. agricultural producers for many years. Since the late 1990s the share of farm workers who migrate in the United States has declined by roughly 60% (Fan et al., 2015). And since 1980, the share of rural Mexicans, the primary source of labor to U.S. farms, working in agriculture has declined by roughly 1% per year (Charlton and Taylor, 2016). Farm labor shortages became more frequent in the 2000s (Hertz and Zahniser, 2013). Though labor shortages are typically local and temporary, they can nevertheless be devastating. Farm producers have responded to the tightening farm labor supply using a variety of strategies, including technology adoption (Clemens, Lewis, and Postel, 2018; Charlton et al., 2019; Hamilton et al., 2020), contracting H-2A agricultural guest workers (Luckstead and Devadoss, 2019; Zahniser et al., 2018), and hiring workers through Farm Labor Contractors (FLCs) (Taylor and Thilmany, 1993).

FLCs can mitigate the risk of a farm labor shortage by matching workers to farm employers and thus reducing frictions in farm labor markets. However, FLCs have sometimes been known to use their ease of mobility to evade legal detection, such as when suspected of hiring unauthorized workers (Taylor and Thilmany, 1993). FLCs may encounter particularly large challenges in reducing the spread of COVID-19 since they often house workers together and transport them to farms on buses. Given the high mobility

of FLC crews and the long incubation period of COVID-19, the virus could potentially spread quickly among crews of farm workers before being detected. Thus, a major farm labor management tool, the use of FLCs, may be inadequate to mitigate risks associated with worker safety during the pandemic.

Farm workers may be particularly susceptible to COVID-19, not only because their work is essential and cannot be performed remotely, but also because farm workers often share a number of characteristics that are correlated with greater risk for COVID-19. Farm workers and their families often live below the poverty line, reside in dense living quarters, and lack access to healthcare and health insurance. According to the National Agricultural Workers Survey (NAWS), 48.92% of farm workers in 2016 reported that they did not have health insurance, 37.04% had not used any type of healthcare services in the United States in the past 2 years, even fewer had used health services in another country, and 19.15% reported that they did not seek medical care because it was too expensive.[2] Policy interventions can only partially offset some of these disadvantages. For example, the Families First Coronavirus Response Act (FFCRA) requires employers with fewer than 500 employees to provide paid sick leave for workers affected by COVID-19. However, employers with fewer than 50 employees can request an exemption, and there is no guarantee that workers will select to take time off from work if they or their family members display coronavirus symptoms even if they are offered paid sick leave.

UC Berkeley School of Public Health (2020) found that 13% of 1,091 farm workers in Monterey County, California tested positive for COVID-19 between July-November 2020. Antibody tests showed that 20.2% of workers had prevalence of antibodies in September and 19.4% of workers in October. Only 58% of those who tested positive for COVID-19 during the study displayed symptoms, demonstrating how difficult it can sometimes be to detect the virus. Within this sample of workers, 37% reported living in crowded housing defined as more than two people per bedroom, and 19% lived with roommates who were of no relation. Approximately 9% of farm workers lived with someone who had

[2]Statistics based on author's analysis of the National Agricultural Workers Survey (NAWS) conducted by the Department of Labor, Employment and Training Administration, which surveys farm workers at the workplace and is designed to be nationally representative of the crop workforce excluding H-2A workers.

been diagnosed with COVID-19 within two weeks prior to their interview, and 43% of workers lived in housing with shared bathroom or bedroom, thus making it impossible to quarantine if infected. A little more than a third of workers said that they traveled to work with people from outside of their household, and 11% said that they had at least one co-worker quarantined or isolated within the past two weeks.

Among workers who said they had experienced COVID-19 symptoms, 57% said that they went to work while they had symptoms. In most cases, workers said that they continued to work because they felt well enough to do so. An additional one-quarter said that they came to work because they were concerned about losing pay, and 13% said that they were concerned about losing their job if absent. When asked whether they would get vaccinated when a vaccine became available, only 52% of workers said that they were extremely likely to, and 11% said that they were either unlikely or very unlikely to do so. Thus, even as vaccines become available, the risk of COVID-19 exposure in the farm industry may not disappear, at least not right away, and it may be difficult to determine if someone has been positively exposed to COVID-19 since many either do not show symptoms or feel well enough to continue working while symptomatic.

Lack of legal work authorization can further contribute to farm workers' vulnerability to COVID-19. An estimated 48% of farm workers, excluding H-2A guest workers, are unauthorized immigrants.[3] Many farm workers may be fearful of seeking public services, including healthcare or legal services if they believe that their immigration status might be exposed or if they believe that someone might try to deport them or their friends or family. H-2A workers may be less vulnerable to some of these challenges in obtaining services since they have legal documentation to work in the United States.[4] However, their working conditions and access to legal and health services likely vary. Since H-2A workers can only legally work for one employer during their residence in the United

[3]Statistics based on author's analysis of the National Agricultural Workers Survey (NAWS) conducted by the Department of Labor, Employment and Training Administration, which surveys farm workers at the workplace and is designed to be nationally representative of the crop workforce excluding H-2A workers.

[4]H-2A workers constitute an estimated 10% of the full-time equivalent farm workforce (Costa and Martin, 2020).

States, some H-2A workers may not be aware of the services that are available to them or may fear that certain actions would jeopardize future employment.

Farm worker ethnicity also plays a role in susceptibility to COVID-19. An estimated 81% of farm workers in 2016 were of Hispanic descent, not including H-2A workers.[5] Hispanics appear more likely to get COVID-19 and more likely to have severe symptoms. Hispanics experience an estimated 5-7-fold risk of COVID-19 mortality compared to Whites (UC Berkeley School of Public Health, 2020). Even though Hispanics represented only 24% of workers in industries with the highest rates of COVID-19 outbreaks in Utah, they made up 73% of the COVID-19 cases in those industries (Bui et al., 2020).

Many employers are implementing policies to reduce the risk of spreading COVID-19 while working in the fields, but measures also need to be taken to increase social distancing in worker housing and transportation. Some FLCs have rented additional buses to transport workers to worksites or made additional trips with the same bus to increase social distancing on the bus (Beatty et al., 2020). Some of the employers who provide housing for farm workers are housing fewer workers per living unit and designating quarantine housing for workers who show symptoms of COVID-19. These measures could be vital in preventing a COVID-19 outbreak, but they also increase the marginal cost of employing each worker. Employers in Washington sued the Departments of Health and Labor & Industries, stating that it was impossible to comply with the emergency COVID-19 safety regulations, including restrictions on distance from a hospital emergency room, and employers in Oregon have requested the repeal of emergency rules stipulating increased spacing between beds in farm worker housing. Some employers state fears that if emergency housing rules are not repealed, the incidence of farm workers sleeping in informal housing, including vehicles, will likely rise (Rural Migration News, 2021). The increased cost of emergency worker safety provisions could lead some producers to take negligent actions while the risk of COVID-19 spread is still high. Other producers might

[5]Statistics based on author's analysis of the National Agricultural Workers Survey (NAWS) conducted by the Department of Labor, Employment and Training Administration, which surveys farm workers at the workplace and is designed to be nationally representative of the crop workforce excluding H-2A workers.

consider investing in labor-saving technologies to reduce labor costs and mitigate risks to farm worker health or the risk of encountering a farm labor shortage.

Prior to the coronavirus pandemic, many fruit and vegetable producers were already experimenting with new technological innovations to reduce labor inputs in production and harvest. For example, Taylor Farms of Salinas, California began installing robotic arms that package salads in its processing facility. In the fields, they harvest with automated lettuce harvesters that use patented jet knife technology to cut the Romaine heads near the ground. The harvester then delivers the Romaine heads to workers who inspect and sort them on the harvester's platform. These harvesters arguably improve workers' safety by removing the need for workers to bend over rows of lettuce, wielding machetes, for several hours everyday. Taylor Farms says these innovations reduce their risk of labor shortages and provide opportunities for workers in higher-skilled, better-paying jobs.[6]

Increased uncertainty in farm labor supply, worker health and safety, along with increasing risk of farm labor shortages associated with COVID-19 could accelerate the development and adoption of labor-saving technologies. New strategies to slow the spread of COVID-19 among farm workers, including extra bus transportation, providing quarantine housing, spacing workers, providing additional sick leave, and providing personal protective equipment is costly to producers. Furthermore, increasing COVID-19 cases during peak harvest seasons poses enhanced risk of a labor shortage and loss of harvested crop. A positive relationship between farm employment and new COVID-19 cases could lead to increased mechanization. As Taylor farms found with the mechanized lettuce harvester, labor-saving innovations can potentially improve worker safety and generate higher paying jobs. Historically, some farms and workers have benefited from the development of labor-saving technologies while others did not (Schmitz and Seckler, 1970).

[6]See Taylor Farms. "The Automated Farm" August 22, 2017. https://www.taylorfarms.com/news/the-automated-farm/. Accessed August 28, 2020.

Data

Sector-specific employment data come from the U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW). The QCEW records employment and wages for establishments that report to U.S. Unemployment Insurance (UI) programs. As a measure of FVH employment each month, I sum employment in orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339). I also include a proxy for employees of Farm Labor Contractors (NAICS 115115). Importantly, I drop all counties that do not report any agricultural employment in FVH sectors, grain and oilseed sectors (NAICS 1111), other crop sectors (NAICS 1119), or livestock sectors (NAICS 112).

I make a minor adjustment to the NAICS 115115 employment by FLCs since employees of FLCs may not work in the county of their employer's address. I proxy for the FLC employment for each county-month observation based on the county share of contract labor expenditures in each state in the 2017 Agricultural Census. I multiply the Agricultural Census county share of contract labor expenditures in the state by the QCEW number of FLC employees in the state each month. I use the resulting product as a proxy for county FLC employment, and if data in the Agricultural Census data, I replace the proxy with the county FLC count in the QCEW. The July FLC counts by county in the QCEW and the FLC proxy based on county shares of contract labor expenditures in the 2017 Agricultural Census are plotted in the maps in figure 1. As expected, the locations of FLC workers in the proxy are more geographically spread than the counts taken directly from the QCEW. As a robustness check, I repeat the analysis using the county-by-month FLC counts directly from the QCEW instead of the proxy. Results are in the appendix.

Figure 2 plots the 2019 national monthly employment in FVH (including FLC) sectors, grain and oilseeds, other crops, livestock, and post-harvest agricultural activities. FVH and FLC employment range from about 375-540 thousand workers, peaking in July. Grain

and oilseed sectors employ only a maximum of 40,000 workers during the year, other crops about 55,000, and livestock a little less than 234,000. Post-harvest crop activities employ only a maximum of 85,000 workers. However, one might be concerned that employment in fruit packing sheds is highly correlated with employment in FVH sectors and prone to risk of COVID-19 spread since workers typically work indoors where there might be less air flow. As a robustness check, I control for monthly post-harvest activity employment.

Figure 3 plots national monthly employment in FVH crops in 2019. Seasonal employment varies across crops, and FLCs have the highest employment compared to any individual crop industry.

Figure 4 maps total employment in July 2019 for all FVH sectors. Counties with missing data are those that do not have any agricultural employment reported in the QCEW. Note that some counties do not report any employment in the QCEW and thus are dropped from the sample. FVH employment was particularly high in several counties in California, Oregon, Washington, Idaho, Florida, Michigan, and parts of the Northeast.

One concern with the QCEW is that industry employment is sometimes suppressed when there are few firms located in the county and identification of individual firms might be possible. This causes an undercount of employees in some counties. Measurement error from suppression should theoretically be quite small since only counties with few firms (and thus likely relatively few employees) will be suppressed. However, there may be exceptions and as a robustness check, I repeat the analysis dropping all counties that have suppressed employment in any of the FVH sectors listed above, including FLCs. Results are reported in the appendix.

A second concern is that the QCEW sums employment by industry using unemployment insurance (UI) records, and employers in some states require employers to report H-2A to UI while others do not. H-2A workers constituted an estimated 10% of the full-time equivalent crop workforce in 2019 (Costa and Martin, 2020). North Carolina, Georgia, Florida, Washington and California employed more H-2A workers than any other state from 2015-2019, and in 2019 (and most previous years) H-2A employment

in the least of these states was more than twice that of the next state.[7] Undercounting H-2A workers, particularly in the top 5 states, could be of concern for this analysis. Personal phone conversation with North Carolina Division of Employment Security in 2019 revealed that North Carolina does not record H-2A workers in the UI. Georgia was unable to reveal whether farms report H-2A in the UI, and according to Rural Migration News (2020) Florida does not record H-2A employees in the UI, while California and Washington do. As a robustness check, I repeat the analysis, dropping all counties with suppressed FVH employment and all counties in North Carolina, Georgia, and Florida. Results are reported in the appendix.[8]

COVID-19 case and death data come from the *New York Times*, which compiles cumulative counts of coronavirus cases and deaths at the county level over time from state and local governments and health departments. I assume that missing values in the COVID-19 data are zeroes since most counties did not report COVID-19 cases and deaths prior to detecting COVID-19 in the county, and I difference the data to find new cases and deaths. Note that there is uncertainty and measurement error in COVID-19 case and death data.[9] However, these data should serve as a reasonable proxy for changes in the incidence of COVID-19.

Data are summarized in table 1. Employment is measured in hundreds of workers. The mean number of FVH workers (excluding FLCs) in the sample is 141 per county-month observation. Mean FLC employment is slightly higher (910 workers) using the proxy compared to the direct count in the QCEW (861 workers). There is a mean of 355 post harvest workers per county-month observation. The mean number of COVID-19 cases per county grew from 327.67 in April to 2,195.76 in August. Mean COVID deaths

[7]Based on author's analysis of the Office of Foreign Labor Certification Disclosure Data.

[8]Another source of under-counting are farms with few employees, which are not required to file with UI in certain states. Since only small employers are exempt from filing this should have a relatively small source of measurement error.

[9]Note that the Centers for Disease Control and Prevention (CDC) asserts that COVID-19 counts are provisional and may need to be updated. See, for example, Centers for Disease Control and Prevention (September 1, 2020) "Daily Updates for Totals by Week and State: Provisional Death Counts for Coronavirus Disease 2019 (COVID-19)." https://www.cdc.gov/nchs/nvss/vsrr/covid19/index.htm. Accessed September 1, 2020.

rose from 16.44 to 59.69. There was a mean of 428.76 COVID-19 cases and 11.76 deaths per county-month observation.

Model

I measure the association between month-to-month variation in agricultural employment and COVID-19 growth within counties by estimating the following equation:

$$Y_{i,m,2020} = \beta FVH_{i,m,2019} + \sum_k \alpha_k hr_{k,i,m,2019} + \gamma_{s,m} + April_i \cdot \eta_m + \rho_i + \epsilon_{i,m}$$

where $Y_{i,m,2020}$ is the outcome of interest in county i in month m in 2020, $FVH_{i,m,2019}$ is employment in FVH sectors in county i month m in 2019, $hr_{k,i,m,2019}$ is employment in "higher risk" non-agricultural industry k, $\gamma_{s,m}$ is a vector of state-by-month fixed effects, $April_i \cdot \eta_m$ is a vector of indicator variables for county exposure to COVID-19 in April 2020 interacted with month fixed effects, ρ_i is a vector of county fixed effects, and $\epsilon_{i,m}$ is the error term.

Outcomes of interest include the inverse hyperbolic sine transformation (denoted arcsinh) of new COVID-19 cases reported in the county each month, and new COVID-19 cases and deaths per 100,000 individuals in the 2019 monthly workforce. Previous literature examines the effects of shelter-in-place orders (Dave et al., 2020b; Friedson et al., 2020) and early college spring break (Mangrum and Niekamp, 2020) on the natural log of COVID-19 cases, thus accommodating a nonlinear relationship between the explanatory variable and COVID-19 incidence, which is likely appropriate when modeling a virus that spreads through personal interactions within a population. This paper differs from previous literature in that I examine COVID-19 spread primarily in rural counties, many of which had none to a few COVID-19 cases in some months from April-August. To account for a potentially nonlinear relationship between agricultural employment variation and COVID-19 case growth and to reduce the influence of outliers (Bellemare and Wichman, 2020), I use the inverse hyperbolic sine transformation (denoted arcsinh) of COVID-19 cases. The inverse hyperbolic sine transformation is similar to the natural log with the

important distinction that it is defined even for values of zero,[10] which is important in my analysis of rural counties since many had zero confirmed COVID-19 cases as the start of the panel. Second, I measure effects on COVID-19 cases and deaths per 100,000 workers in the 2019 workforce, using monthly workforce measures from the QCEW.

The controls for "higher risk" non-agricultural employment include employment in industries that typically experience seasonal changes in labor demand and where workers cannot easily work remotely. These industries, defined by subscript k, include post-harvest crop activities, construction, retail trade, and accommodation and food.[11]

Since employment measures come from 2019, prior to the COVID-19 pandemic or any knowledge of it, the pandemic had no effect on hiring decisions in the explanatory variable. State-by-month fixed effects control for statewide growth in COVID-19, including shocks to COVID-19 growth potentially due to changes in state health mandates. County fixed effects control for time-invariant characteristics of the county. Standard errors are clustered at the county.

One might be concerned that COVID-19 grew faster in counties that had higher exposure to COVID-19 near the start of the pandemic, and this might be correlated with historical changes in farm employment during the agricultural growing and harvesting seasons. To account for this possibility, I additionally control for a vector of indicator variables for intensity of COVID-19 exposure as of April 2020 interacted with month fixed effects. I create the vector for COVID-19 intensity using indicator variables that divide counties into 12 groups. Group sizes vary somewhat so as to keep together counties with the same number of COVID-19 cases in April. The low-intensity groups contain more counties than higher intensity groups since many counties had none or very few cases in April.

It is important to note the limitations of causal interpretation in this analysis. Specifically, agricultural labor activity may be correlated with other activities that are relatively

[10] The inverse hyperbolic sine of x is defined $arcsinh(x) = ln(x + \sqrt{x^2 + 1})$.

[11] I also repeated the analysis additionally controlling for employment in transportation and warehousing, healthcare and social services, other service industry, and the meat processing sector. I do not include all of these controls in the main analysis because these industries do not typically experience large variation in employment within the year. However, the addition of more sector employment controls had little to no effect on the estimated coefficients on FVH employment.

high risk for spreading the COVID-19 virus. I expect that many correlated activities are absorbed in state-by-month fixed effects, but changes in housing density, communal living, or shared transportation, which may be directly related to changes in farm labor, will not be absorbed in fixed effects. This investigation does not provide sufficient evidence to suggest that on-farm activities themselves increase the risk of spreading COVID-19, but it does provide insights into which crops and activities likely bear greatest risk of COVID-related disruptions to labor supply.

Results

Main results are presented in table 2. The dependent variable in columns 1-2 is the inverse hyperbolic sine transformation of new COVID-19 cases at the county-month. The dependent variable in columns 3-4 is new COVID-19 cases per 100,000 individuals in the 2019 monthly workforce, and the dependent variable in columns 5-6 is COVID-19 deaths per 100,000. All specifications include county fixed effects, state-by-month fixed effects, and controls for county level of exposure to COVID-19 in April interacted with month fixed effects. Even columns additionally include controls for historical monthly employment in seasonal industries where working from home might not be possible.

The results in columns 1-2 show that 100 additional workers in the historical monthly FVH workforce were associated with a 2.27-4.54% increase in COVID-19 cases.[12] These semi-elasticities are based on mean FVH employment of 227 workers per county during the sample period. Similarly, 100 additional historical FVH workers were associated with 21.12-25.17 additional COVID-19 cases and 0.34-0.48 deaths per 100,000 individuals in the historical monthly workforce. All coefficients are statistically significant at the 1% level.

I find a statistically significant negative coefficient on historical employment in post-harvest crop activities in columns 1 and 3. However, given that post-harvest crop employment is correlated with FVH employment, one should use caution in interpreting these

[12]Semi-elasticities are calculated by multiplying the coefficient by the mean value of the explanatory variable (Bellemare and Wichman, 2020).

coefficients apart from the coefficients on FVH employment. I do not find statistically significant coefficients on employment in other non-farm sectors. More importantly, inclusion of the additional controls leads to slightly larger coefficients on FVH employment, but no substantive changes on the coefficients of interest.

Table 3 shows the results from measuring the association between historical employment in individual crop industries and COVID-19 cases and deaths in 2020. The dependent variable in the first column is the inverse hyperbolic sine transformation of new COVID-19 cases at the county-month, in the second column, new COVID-19 cases per 100,000 individuals in the historical workforce, and in the third column, new COVID-19 deaths per 100,000. The results show a statistically significant positive relationship between berry employment and COVID-19 deaths per capita, grape employment and COVID-19 cases per capita, other non-citrus fruit employment and COVID-19 cases and deaths, vegetable and melon employment and COVID-19 cases per capita, and greenhouse employment and COVID-19 cases.

The coefficients on greenhouse employment in columns 1 and 2 are very large (though statistically significant only at the 10% level). These results would suggest that 100 additional greenhouse employees in 2019 were associated with a 16% rise in COVID-19 cases or 367 new cases per 100,000 individuals in the monthly 2019 workforce. Risk of COVID-19 spread might be particularly high among greenhouse employees because work is performed indoors. However, one should take caution in interpreting coefficients causally, as employment in various fruits and vegetables may be correlated. Results are nevertheless suggestive of what fruits and vegetables might have been exposed to particularly high risk of COVID-related labor disruptions in 2020. It is notable that FLC employment, which is often used to mitigate the risk of farm labor shortages, was also associated with a statistically and economically significant increase in the incidence of COVID-19. Employment of 100 additional FLC workers in 2019 was associated with a 2.58% increase in COVID-19 cases within the county and 35.54 additional COVID-19 cases and 0.69 deaths per 100,000 in the 2019 monthly workforce.

I find no significant association between employment in more mechanized crops, including grains and oilseeds and other crops (mostly field crops), or animal and livestock and new COVID-19 cases or deaths. This suggests, not surprisingly, that crops with large seasonal work forces faced greatest risk COVID-related labor disruptions during labor-intensive months of the year.

Discussion

The findings in this paper suggest that there is a large, statistically significant positive association between month-to-month changes in agricultural employment within counties and new COVID-19 cases. However, the analysis does not illuminate the precise mechanisms of this relationship. It is notable that increased FLC employment is associated with positive, statistically significant estimated marginal effects. Employees of FLCs are migratory and thus may be both more susceptible to picking up the virus as they travel between farms and to spread viruses with other workers who may share housing, transportation, or social activities.

Numerous factors may correlate with both changes in agricultural employment and new COVID-19 cases. For example, the majority of farm workers in the United States are Hispanics, and Hispanics appear to be more susceptible to COVID-19 than other races. In California, there were 1,750.3 COVID-19 cases for every 100,000 Hispanic residents in August 2020, compared to just 514.3 cases per 100,000 White residents and 438.9 cases per 100,000 Asian residents (Ibarra, Castillo, and Yee, 2020).[13] In addition, newspaper reports suggest that misinformation surrounding COVID-19 is more prevalent in Hispanic communities, likely stemming from greater distrust in government, worse access to medical care, and language barriers (Klepper, Sainz, and Garcia Cano, 2020). If Hispanics are more susceptible to COVID-19 than other races, then the migration of Hispanic farm workers into communities as agricultural labor demand rises, or increased

[13]Race/ethnicity was unknown for 231,446 (34.1%) of cases in the cited study. The only ethnicity that surpasses the Hispanic COVID-19 rate is Native Hawaiian and Pacific Islander with 1,834.3 cases per 100,000 residents.

activity and increased interactions between different social circles of Hispanic households during peak farm labor seasons, could increase COVID-19 cases within the county.

The results do not indicate that COVID-19 is necessarily spreading on farms, and understanding how or why COVID-19 is spreading in farm labor communities is beyond the scope of this paper. Many labor activities on farms could involve relatively high risk of spreading COVID-19, particularly when it is difficult to distance workers. Nevertheless, many farms and FLCs have taken precautions to reduce social contact on the farm, including assigning workers to the same work crews each day, taking additional trips to transport workers to worksites on buses, taking workers' temperatures each day, spreading workers in the field, and providing additional wash stations in the fields. If workers share seasonal housing with one another, cook and eat meals together, or share childcare responsibilities among several families, among other shared activities, then COVID-19 could spread in seasonal farm labor communities even if the work environment is relatively safe.

Identifying the mechanisms that link labor-intensive agricultural crop production to new COVID-19 cases is beyond the scope of this paper. Yet, the positive relationship between FVH employment and the incidence of new COVID-19 cases found in this paper illustrates how a pandemic like COVID-19 could drastically increase labor uncertainty and health risk during critical stages of agricultural production. Traditionally, FLCs have helped reduce labor supply uncertainty and labor market frictions by matching employers to work crews for seasonal or temporary tasks. However, if FLC workers are similarly vulnerable to catching or spreading the virus, as the results in this paper suggest, hiring workers through FLCs may not be a viable farm labor management strategy.

Despite growing COVID-19 incidence in geographic locations and months when farm employment was increasing, there have been relatively few major disruptions in agricultural production. According to (Martin, 2020), there were few COVID-19 outbreaks on farms during 2020, and fruit shipments remained steady throughout the year. However, heightened farm labor supply uncertainty and increased labor costs could induce more producers and managers up and down the food supply chain to make new invest-

ments in labor-saving technologies. Farms with greater production risk, and farmers with better information about technologies that reduce production risk typically place lower option value on the decision to wait to adopt a new, risk-reducing technology (Koundouri, Nauges, and Tzouvelekas, 2006). Increased risk of labor shortages combined with increased marginal cost of labor to implement social distancing and safety measures on-farm and in employer-provided housing could spur increased efforts to mechanize production of labor-intensive crops.

Investments in developing labor-saving technologies are expected to emerge first for the most vulnerable agricultural activities with the most accessible technological innovations and gradually expand to more crops and more geographical settings, similar to Griliches (1957) findings for the diffusion of hybrid corn. Labor-saving technologies are already commercially available for some fruits and vegetables that were traditionally harvested by hand. For example, some wine grapes are already harvested mechanically, but many vineyards have not converted to mechanical harvest, possibly due to high up-front cost, poor adaptability of terrain to harvesting machinery, or a desire to maintain specific quality characteristics associated with hand-picked grapes (Taylor and Charlton, 2014). However, costly measures to help reduce the risk of spreading COVID-19 among farm workers could lead some wine makers to replace trellis systems and equip vineyards for mechanical harvest.

Numerous variables factor into a producer's decision to adopt a new technology, and producers are not homogeneous. Just and Zilberman (1988) find that the joint distribution of risk preferences, farm size, access to credit, and the stochastic structure of alternative production activities is critical in determining who adopts a new technology and who benefits from government policies to encourage adoption. Interest rates dipped down to historical lows during the coronavirus pandemic, potentially reducing the costs of capital investments, and government appropriations to agricultural producers could influence producers' production and investment decisions in the short-term.

Conclusion

This paper measures the relationship between historical month-to-month variation in agricultural employment within counties and new cases of COVID-19 and deaths each month from April-August 2020. The results show that 100 additional workers in the 2019 monthly fruit, vegetable, and horticultural (FVH) workforce in were associated with a 4.5% increase in COVID-19 cases, and 25.17 additional COVID-19 cases and 0.48 COVID-19 deaths per 100,000 individuals in the 2019 monthly workforce. If farm workers are less likely to get tested for COVID-19 as some reports suggest (UC Berkeley School of Public Health, 2020), then these estimated coefficients could be lower-bounds for the actual association between FVH employment and the incidence of new COVID-19 cases and deaths within a county.

All specifications include controls for state-by-month fixed effects and indicator variables for level of exposure to COVID-19 in April 2020 interacted with month fixed effects, but do not preclude the possibility that other social activities correlated with agricultural employment could be responsible for the observed relationship. Nevertheless, the findings have important implications for agricultural producers and consumers. Outbreaks of COVID-19 in agricultural communities as employment rises increase the risk of farm labor shortages at critical stages of production and harvest. Potential health risks to workers are a public concern, and new strategies may need to be implemented to help protect farm workers' safety. Labor shortages could be costly to individual producers, and in the extreme event, labor shortages could lead to regional or national food shortages for consumers.

Understanding sector-specific vulnerabilities associated with unanticipated shocks to worker health risk and labor supply is paramount for policymakers, industry leaders, rural planners, and agricultural producers to make informed risk management strategies. Employer policies to increase social distancing in the workplace likely slow the spread of COVID-19. However, these precautions come at considerable cost to the employer and do not entirely remove the risk of COVID-19 outbreaks.

One of the often used strategies to reduce labor market frictions when the farm labor supply is tight is to hire workers through FLCs. However, findings in this paper suggest that FLC crews were similarly vulnerable to the spread of COVID-19 in 2020. Investments in new labor-saving or labor-augmenting technologies that increase labor productivity were already underway for FVH crops prior to the pandemic due, in large part, to the tightening farm labor supply over the past several decades (Charlton et al., 2019; Hamilton et al., 2020). Increased risk with respect to worker safety and labor supply during the pandemic might induce additional producers to invest in mechanized solutions and labor-saving technologies as a risk management strategy (Koundouri, Nauges, and Tzouvelekas, 2006), likely beginning with the farms that are most vulnerable to labor shortages (Griliches, 1957) or that experienced the largest increases in labor costs.

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I. Appendix

In the main analysis, I proxy for FLC employment using the county share of contract labor expenditures in the state according to the 2017 Agricultural Census interacted with the number of FLC workers at the state-month in the 2019 QCEW. As a robustness check, I repeat the analysis using the number of FLC workers in the county-month as recorded directly in the QCEW. Results are reported in tables 4 and 5. Findings are similar to those in tables 2 and 3, though the coefficients are somewhat smaller using the county FLC counts from the QCEW. Most notably, the coefficients on FLC employment in table 5 are not statistically significant in 2 out of the 3 specifications.

I additionally repeat the analysis using a number of robustness checks due to concerns about urban influence on COVID-19 spread, data suppression in the 2019 QCEW, and potential correlation between crop employment and workplace COVID-19 outbreaks in meat processing plants. First, one might be concerned that exposure to rapidly spreading COVID-19 incidence in urban areas influences the results. As a robustness check, I limit the sample to rural (non-metropolitan) counties.[14] Figure 5 shows the geographic distribution of rural counties in a U.S. map. Results using rural counties only are reported in in panel A of table 6. The estimated coefficients on FVH employment are statistically significant in all three specifications and slightly larger than in table 2.

The QCEW suppresses employment data when there are few employers within a county-month observation or when it might be possible to identify a single firm using the county aggregated data. In the main analysis, I replace suppressed employment with zero employment since in most cases, there are likely relatively few workers in the suppressed industry. However, as a robustness check, I drop all counties with suppressed data in any one of the FVH sectors of interest. A map of the counties retained after dropping suppressed employment data is in figure 6. The results after dropping counties with suppressed FVH or FLC employment are in panel B. Coefficients for the association between FVH employment and new COVID-19 case incidence in columns 1-4 are quite

[14]Rural classification is based on the Office of Management and Budget (OMB) 2013 Urban Influence Codes.

a bit larger than in table 2. However, the coefficients in columns 5-6 for the association with new COVID-19 deaths per 100,000 individuals in the historical workforce are not statistically significant.

In panel C, I additionally drop observations from Florida, Georgia, and North Carolina since these states have a high share of H-2A workers who are not reported in the QCEW. Results are similar to those in panel B.

In panel D, I drop all counties with positive employment in meat packing plants (or suppressed employment data for the meat packing sector). I do not control for employment in meat packing plants in the main analysis because there is little month-to-month variation in employment. However, one might be concerned that worksite outbreaks of COVID-19 in rural meat packing plants in 2020 might correlate with changes in FVH employment and thus bias results. Figure 7 shows which counties were retained after dropping those with meat processing employment. The results in panel D are similar to those in table 2, suggesting that COVID-19 outbreaks in meat processing plants had little correlation with monthly variation in historical FVH employment.

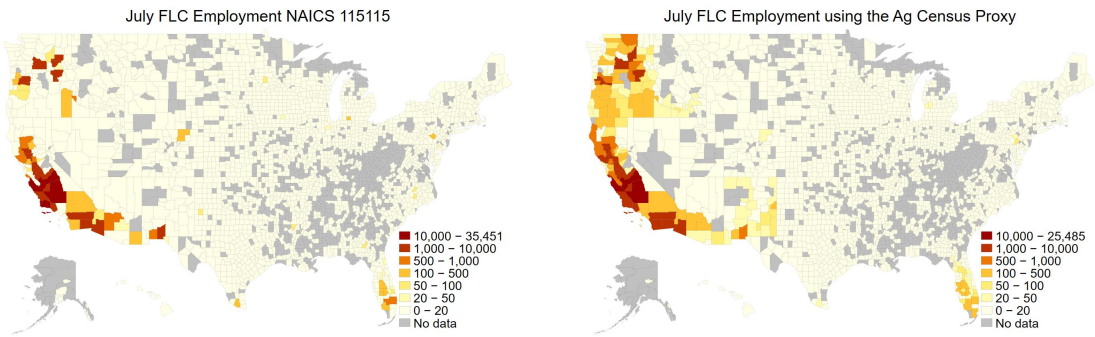
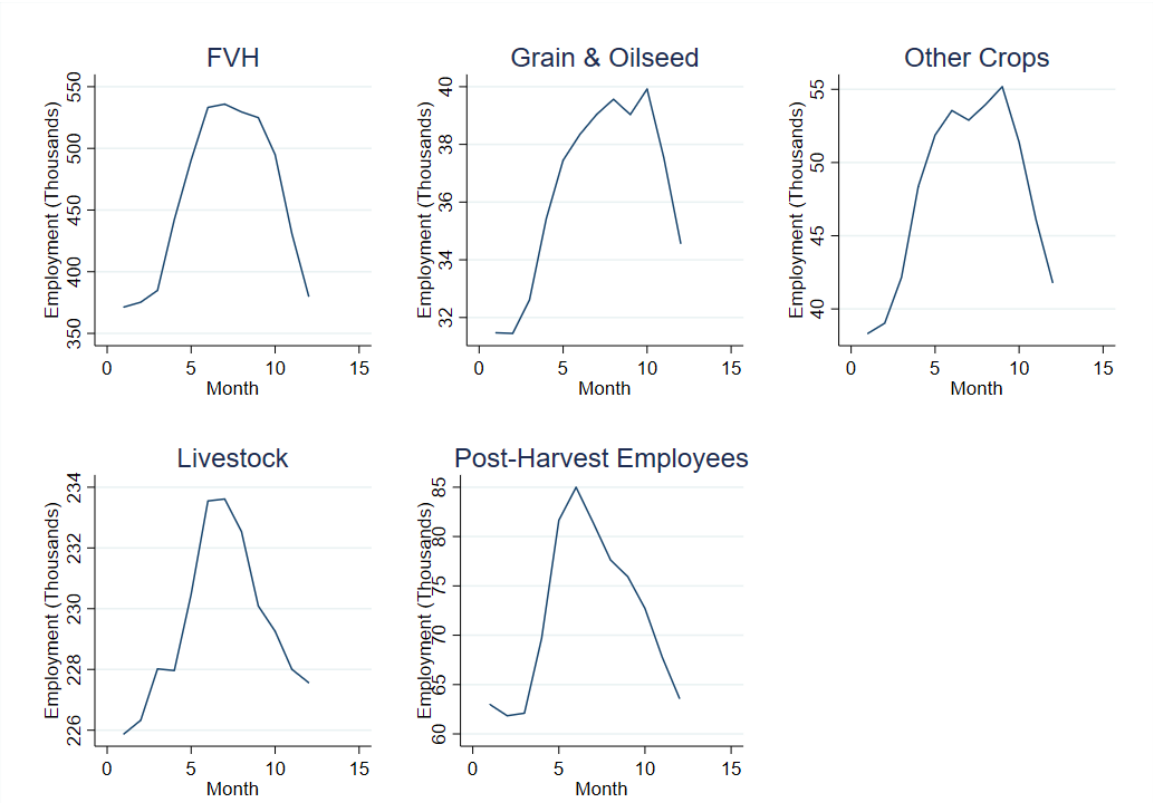


Figure 1: FLC QCEW Count Compared to the FLC Agricultural Census Proxy



Note: FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339), and FLCs.

Figure 2: National monthly employment in FVH and other agricultural sectors (2019)

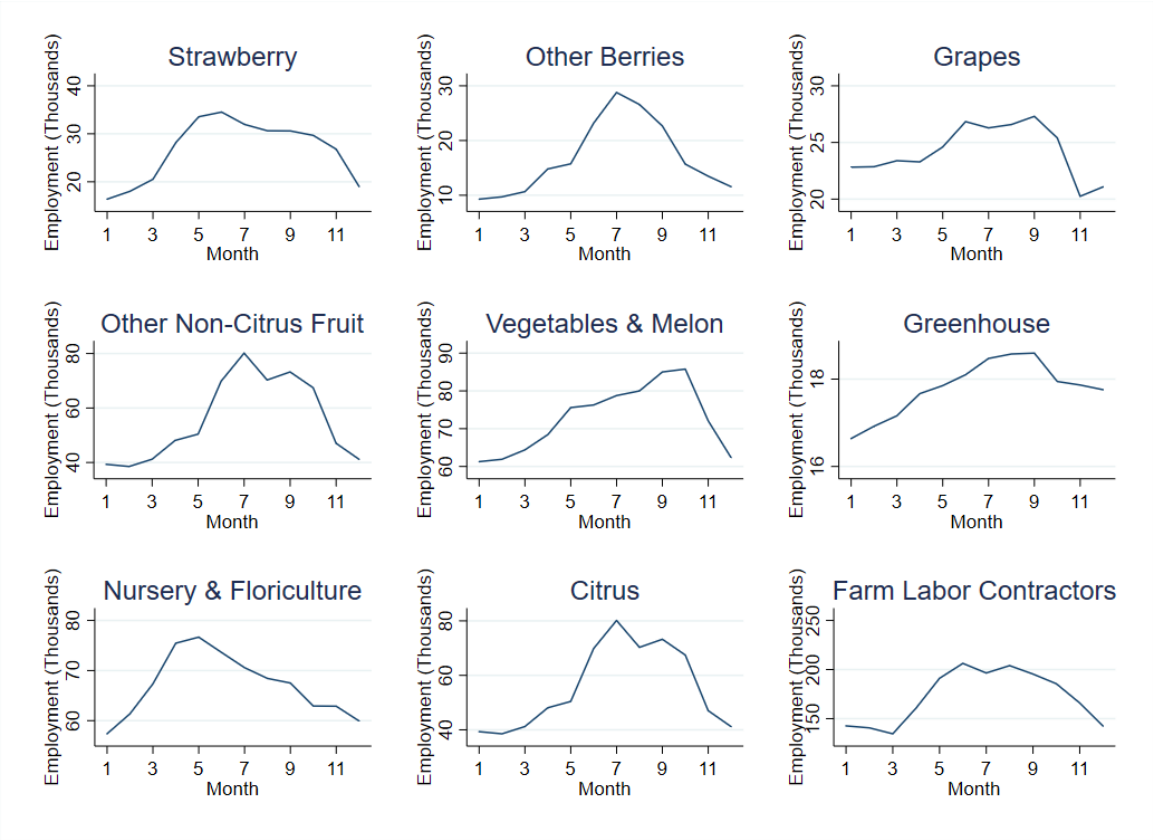
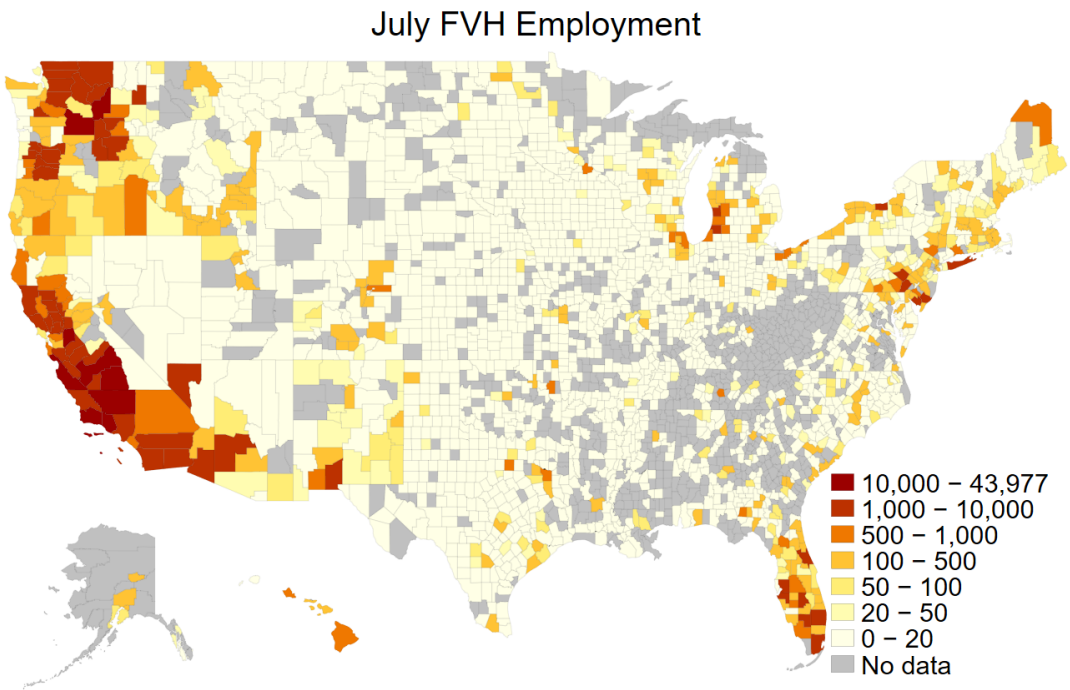


Figure 3: National monthly employment by crop (2019)



Note: FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339), and FLCs.

Figure 4: Geographic variation in peak FVH employment (July 2019)

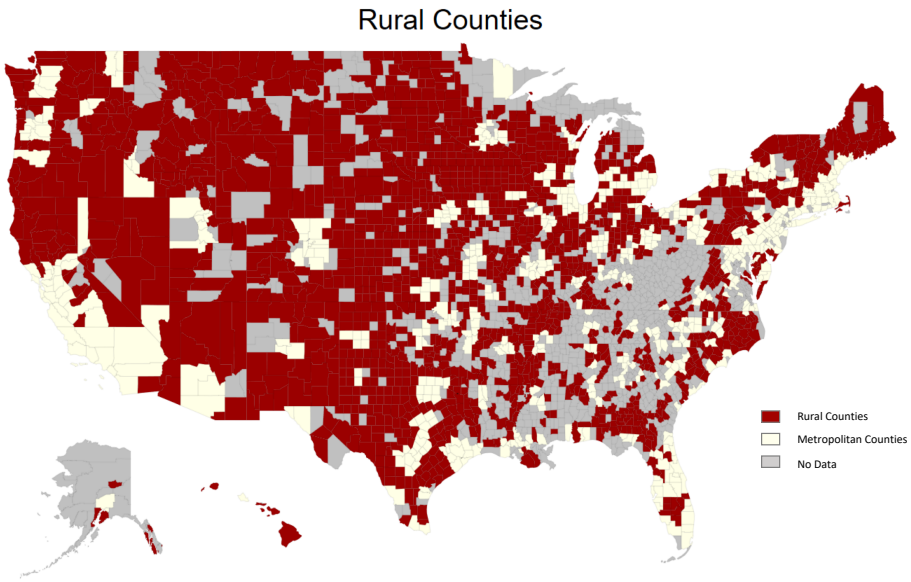


Figure 5: Designated rural counties

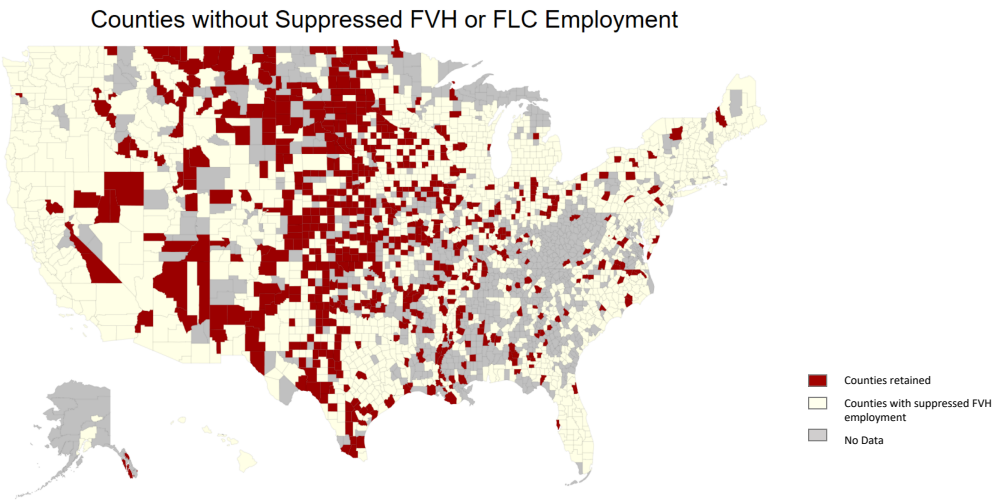


Figure 6: Counties without FVH employment suppression

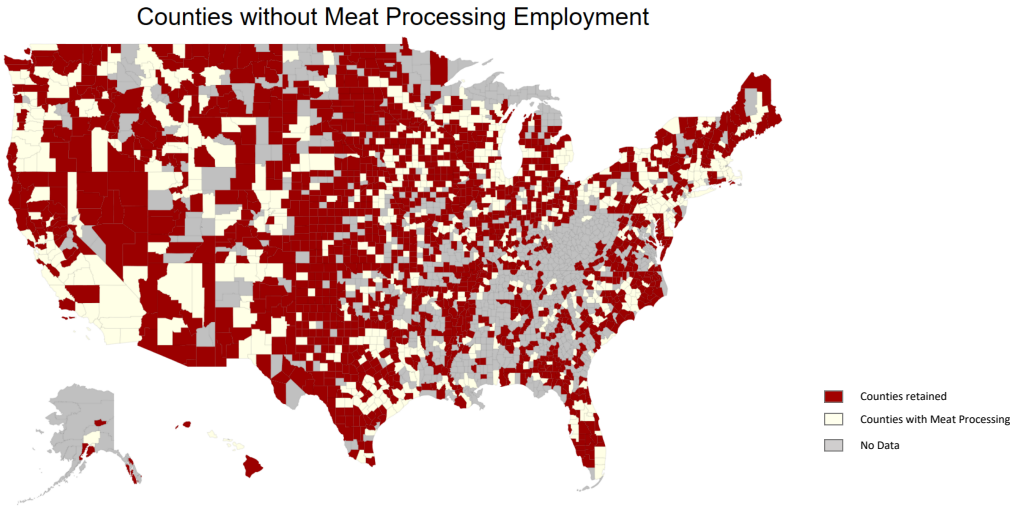


Figure 7: Counties without employment in meat processing

Table 1: Summary Statistics (Counties with Positive Agricultural Employment in 2019)

Variable	Mean	Std. Dev.	Minimum	Maximum	N
Monthly Employment April-August 2019 (Hundreds of Workers)					
Fruit, Vegetable & Horticulture (excluding FLCs) Employment	1.412	9.537	0	247.84	11,140
Farm Labor Contractor Employment Proxy	0.861	9.750	0	274.692	11,140
Farm Labor Contractor Employment (NAICS 1115115)	0.861	12.520	0	478.07	11,140
Post-Harvest Crop Employment	0.355	4.313	0	132.89	11,140
Cumulative COVID-19 Cases and Deaths in 2020					
Cases in April	327.666	1847.573	0	36513	2,228
Deaths in April	16.444	99.380	0	2111	2,228
Cases in August	2195.758	9181.158	0	241768	2,228
Deaths in August	59.687	261.414	0	5784	2,228
New Monthly COVID-19 Cases and Deaths April-August 2020					
Cases	428.763	2236.492	0	84952	11,140
Deaths	11.762	65.820	0	2048	11,140

FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339).

Table 2: Historical monthly FVH employment and changes in the incidence of COVID-19 within counties April-August 2020

	(1) arcsinh(Cases)	(2) arcsinh(Cases)	(3) Cases per 100,000	(4) Cases per 100,000	(5) Deaths per 100,000	(6) Deaths per 100,000
	Historical monthly 2019 employment measured in hundreds of workers					
FVH	0.01***	0.02***	21.12***	25.17***	0.34***	0.48***
	(0.003)	(0.004)	(5.536)	(6.292)	(0.096)	(0.112)
Post-Harvest Activities		-0.01*		-18.21		-0.65**
		(0.008)		(13.139)		(0.322)
Construction		0.01		3.27		0.01
		(0.009)		(10.623)		(0.177)
Retail Trade		-0.00		10.32		-0.13
		(0.007)		(8.021)		(0.240)
Accommodation & Food		0.00		3.79		0.09
		(0.003)		(3.697)		(0.107)
County Fixed Effects	Y	Y	Y	Y	Y	Y
State-by-Month FE	Y	Y	Y	Y	Y	Y
April Exposure-by-Month FE	Y	Y	Y	Y	Y	Y
Observations	11140	11140	11140	11140	11140	11140
R-Squared	0.645	0.646	0.277	0.278	0.204	0.204

Robust standard errors clustered at the county. *** p<0.01, ** p<0.05, * p<0.1. arcsinh is the inverse hyperbolic sine transformation. Employment by industry is measured in hundreds of workers at the county-month. FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339), and FLCs. FLCs are employees of Farm Labor Contractors using the proxy calculated from the 2017 Agricultural Census county share of contract labor expenditures in the state interacted with the QCEW number of FLC employees in the state in 2019 (NAICS 115115). All specifications include county fixed effects, state-by-month fixed effects, and an indicator variable for level of COVID-19 exposure in April 2020 interacted with month fixed effects.

Table 3: Historical monthly crop employment and changes in the incidence of COVID-19 within counties April-August 2020

	(1) arcsinh(Cases)	(2) Cases per 100,000	(3) Deaths per 100,000
	Historical monthly 2019 employment measured in hundreds of workers		
Strawberries	-0.00	-10.92	-0.14
	(0.006)	(10.076)	(0.223)
Other Berries	0.01	12.72	0.58***
	(0.007)	(7.795)	(0.219)
Grapes	0.01	51.01**	0.56
	(0.009)	(21.366)	(0.763)
Other Non-Citrus Fruit	0.02***	32.55***	0.57***
	(0.006)	(6.743)	(0.184)
Citrus Employment	-0.03	-60.74	-3.01
	(0.099)	(299.677)	(3.868)
Vegetables & Melons	0.02	49.43**	0.29
	(0.016)	(24.559)	(0.900)
Greenhouse	0.26*	366.90*	8.70
	(0.153)	(195.921)	(6.619)
Floriculture & Nursery	0.03	-11.04	-0.75
	(0.030)	(48.519)	(0.997)
Grain & Oilseed	0.07	152.99	2.83
	(0.112)	(123.837)	(3.991)
Other Crops	0.06	66.70	0.14
	(0.063)	(67.862)	(1.283)
Animals & Livestock	-0.04	-64.49	-2.68
	(0.043)	(85.277)	(2.406)
Farm Labor Contractor	0.03***	35.54***	0.69**
	(0.009)	(13.008)	(0.320)
Post Harvest Activities	-0.02*	-22.61*	-0.74**
	(0.009)	(13.022)	(0.330)
Construction	0.01	3.06	0.01
	(0.009)	(10.627)	(0.177)
Retail Trade	-0.00	9.12	-0.15
	(0.007)	(7.977)	(0.240)
Accommodation & Food	0.01	4.33	0.10
	(0.003)	(3.737)	(0.108)
County Fixed Effects	Y	Y	Y
State-by-Month FE	Y	Y	Y
April Exposure-by-Month FE	Y	Y	Y
Observations	11140	11140	11140
R-Squared	0.646	0.278	0.204

Robust standard errors clustered at the county. *** p<0.01, ** p<0.05, * p<0.1. arcsinh is the inverse hyperbolic sine transformation. Employment by industry is measured in hundreds of workers at the county-month. FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339). FLCs are employees of Farm Labor Contractors using the proxy calculated from the 2017 Agricultural Census county share of contract labor expenditures in the state interacted with the QCEW number of FLC employees in the state in 2019 (NAICS 115115). All specifications include county fixed effects, state-by-month fixed effects, and an indicator variable for level of COVID-19 exposure in April 2020 interacted with month fixed effects.

Table 4: Robustness: FVH relation to COVID-19 using QCEW county-month FLC counts in place of the FLC proxy

	(1) arcsinh(Cases)	(2) arcsinh(Cases)	(3) Cases per 100,000	(4) Cases per 100,000	(5) Deaths per 100,000	(6) Deaths per 100,000
	Historical monthly 2019 employment measured in hundreds of workers					
FVH & FLC	0.01***	0.01***	11.69***	12.45***	0.20***	0.25***
	(0.002)	(0.003)	(3.506)	(3.906)	(0.075)	(0.078)
Post Harvest Activities		-0.01		-4.46		-0.42
		(0.008)		(14.433)		(0.332)
Construction		0.01		3.26		0.01
		(0.009)		(10.585)		(0.177)
Retail Trade		-0.00		9.55		-0.14
		(0.007)		(8.037)		(0.240)
Accommodation & Food		0.00		4.10		0.10
		(0.003)		(3.720)		(0.107)
County Fixed Effects	Y	Y	Y	Y	Y	Y
State-by-Month FE	Y	Y	Y	Y	Y	Y
April Exposure-by-Month FE	Y	Y	Y	Y	Y	Y
Observations	11140	11140	11140	11140	11140	11140
R-Squared	0.645	0.646	0.277	0.277	0.204	0.204

Robust standard errors clustered at the county. *** p<0.01, ** p<0.05, * p<0.1. arcsinh is the inverse hyperbolic sine transformation. Employment by industry is measured in hundreds of workers at the county-month. FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339), and FLCs. FLCs are employees of Farm Labor Contractors (NAICS 115115). All specifications include county fixed effects, state-by-month fixed effects, and an indicator variable for level of COVID-19 exposure in April 2020 interacted with month fixed effects.

Table 5: Robustness: Crop industry relation to COVID-19 using QCEW county-month FLC counts in place of the FLC proxy

	(1) arcsinh(Cases)	(2) Cases per 100,000	(3) Deaths per 100,000
	Historical monthly 2019 employment measured in hundreds of workers		
Strawberries	0.00	-4.99	-0.07
	(0.007)	(8.293)	(0.184)
Other Berries	0.01	13.00	0.58***
	(0.007)	(8.185)	(0.219)
Grapes	0.00	57.02*	0.47
	(0.013)	(32.413)	(0.748)
Other Noncitrus Fruit	0.02***	31.39***	0.56***
	(0.006)	(7.208)	(0.181)
Citrus Employment	-0.11	-167.07	-4.96
	(0.076)	(322.877)	(3.296)
Vegetables & Melons	0.03*	58.08**	0.44
	(0.016)	(26.085)	(0.864)
Greenhouse	0.28*	398.84*	9.27
	(0.156)	(212.601)	(6.701)
Floriculture & Nursery	0.03	-12.25	-0.78
	(0.030)	(49.170)	(0.996)
Grain & Oilseed	0.06	150.15	2.74
	(0.112)	(125.155)	(4.023)
Other Crops	0.07	81.26	0.43
	(0.060)	(65.107)	(1.319)
Animals & Livestock	-0.04	-61.34	-2.64
	(0.042)	(82.546)	(2.356)
Farm Labor Contractor	0.01*	3.75	0.15
	(0.004)	(5.949)	(0.131)
Post Harvest Activities	-0.01	-9.77	-0.52
	(0.009)	(12.702)	(0.324)
Construction	0.01	3.06	0.01
	(0.009)	(10.604)	(0.176)
Retail Trade	-0.00	8.91	-0.15
	(0.007)	(8.036)	(0.241)
Accommodation & Food	0.01	4.26	0.10
	(0.003)	(3.744)	(0.108)
County Fixed Effects	Y	Y	Y
State-by-Month FE	Y	Y	Y
April Exposure-by-Month FE	Y	Y	Y
Observations	11140	11140	11140
R-Squared	0.646	0.278	0.204

Robust standard errors clustered at the county. *** p<0.01, ** p<0.05, * p<0.1. arcsinh is the inverse hyperbolic sine transformation. Employment by industry is measured in hundreds of workers at the county-month. FLC workers are employees of Farm Labor Contractors (NAICS 115115). All specifications include county fixed effects, state-by-month fixed effects, and an indicator variable for level of COVID-19 exposure in April 2020 interacted with month fixed effects.

Table 6: Robustness checks

	(1) arcsinh(Cases)	(2) arcsinh(Cases)	(3) Cases per 100,000	(4) Cases per 100,000	(5) Deaths per 100,000	(6) Deaths per 100,000
Historical monthly 2019 employment measured in hundreds of workers						
A. Rural Counties Only						
FVH & FLC	0.03***	0.03***	45.08***	48.09***	0.41**	0.57**
	(0.008)	(0.011)	(10.050)	(13.647)	(0.204)	(0.242)
Observations	7975	7975	7975	7975	7975	7975
R-Squared	0.625	0.629	0.259	0.260	0.188	0.189
B. Drop Counties with Suppressed Employment in Any FVH Sector (Including FLCs)						
FVH & FLC	0.10***	0.12***	141.78***	101.03*	0.30	2.69
	(0.029)	(0.047)	(26.013)	(54.028)	(1.168)	(1.765)
Observations	3333	3333	3333	3333	3333	3333
R-Squared	0.621	0.625	0.328	0.331	0.209	0.211
C. Drop Counties with Suppressed Employment and States with High Number of Unreported H-2A						
FVH & FLC	0.11***	0.13***	141.38***	99.24*	0.42	2.91*
	(0.026)	(0.044)	(26.815)	(57.563)	(1.064)	(1.646)
Observations	3201	3201	3201	3201	3201	3201
R-Squared	0.620	0.624	0.318	0.322	0.201	0.203
D. Drop Counties with Positive or Suppressed Employment in Meat Processing						
FVH & FLC	0.02***	0.02***	32.22***	39.20***	0.41**	0.51***
	(0.006)	(0.006)	(10.655)	(11.783)	(0.183)	(0.160)
Observations	7815	7815	7815	7815	7815	7815
R-Squared	0.649	0.652	0.260	0.262	0.188	0.189
Non-Farm Employment Controls	N	Y	N	Y	N	Y
County Fixed Effects	Y	Y	Y	Y	Y	Y
State-by-Month FE	Y	Y	Y	Y	Y	Y
April Exposure-by-Month FE	Y	Y	Y	Y	Y	Y

Robust standard errors clustered at the county. *** p<0.01, ** p<0.05, * p<0.1. arcsinh is the inverse hyperbolic sine transformation. Employment by industry is measured in hundreds of workers at the county-month. FVH employment includes employment on orange groves, citrus groves, greenhouse, nursery, and floriculture production, vegetable and melon farming, apple orchards, grape vineyards, strawberry farming, other berry farming, fruit and tree nut combination farming, and other non-citrus fruit production (NAICS 11131, 11132, 11141, 11142, 1112, 111331, 111332, 111333, 111334, 111336, and 111339) and FLCs. FLCs are employees of Farm Labor Contractors using the proxy calculated from the 2017 Agricultural Census county share of contract labor expenditures in the state interacted with the QCEW number of FLC employees in the state in 2019 (NAICS 115115). All specifications include county fixed effects, state-by-month fixed effects, and an indicator variable for level of COVID-19 exposure in April 2020 interacted with month fixed effects. Even columns include controls for employment in non-farm industries with potential seasonal changes in labor demand, including construction (NAICS 23), retail trade (NAICS 44-45), and accommodation and food (NAICS 72).