Employment during the COVID-19 Pandemic: Collapse and Early Recovery

Ou Liu[†] Tam Mai[‡]

This version: August 2020

Abstract

We use monthly Current Population Survey data to document employment changes during the COVID-19 pandemic at the occupation, industry, and metropolitan statistical area (MSA) levels. Over March-April 2020, jobs losses are larger for occupations with higher physical proximity or lower work-from-home feasibility, especially for lower-paying occupations. Non-essential industries also see greater declines in employment. Such occupational and industrial susceptibility to COVID-19 contributes to the variation in employment changes across MSAs: Employment shrinks more for MSAs with larger pre-crisis fractions of workers employed in occupations with higher infection risk. Over April-June 2020, occupations and industries that are hit harder recoup more jobs, but the recovery is only partial. Moreover, the gains are concentrated in lower-paying occupations and a few industries. Taken together, these abrupt changes in employment following the COVID-19 outbreak are unprecedented and potentially have long-term implications for occupational inequality and regional disparity.

JEL codes: I10, J21, J23, J31, R12

Keywords: COVID-19, employment, Great Recession, regional disparity, wage inequality

1 Introduction

Within mere months of its outbreak in the United States, the COVID-19 pandemic and the subsequent social distancing responses have sweepingly disrupted economic activity. This paper stud-

[†]Columbia University, ol2193@columbia.edu

[‡]Columbia University, ttm2119@columbia.edu

ies the dynamics of the labor market since the outbreak of the pandemic and asks the following questions: What has happened to occupations and industries that differ in their susceptibility to the disease and the associated stay-at-home orders? How do these employment changes compare to their counterparts in the Great Recession? What are the implications of the variations in occupational and industrial sensitivity to COVID-19 for employment changes across the income distribution and across regions?

To answer these questions, we first classify occupations by their suitability for remote work or needs for physical contact (Bartik, Cullen, Glaeser, Luca, and Stanton (2020), Dingel and Neiman (2020), Mongey, Pilossoph, and Weinberg (2020)) and rank occupations by their mean wage. We additionally classify industries by their essentialness (US Department of Homeland Security (2020)) and group them into general sectors (manufacturing and broadly-defined services). These occupation and industry categorizations serve as the basis for defining our measures of pre-COVID-19 occupational and industrial compositions at the regional level. The unit of region of interest is the metropolitan statistical area (MSA). To obtain our empirical results, we apply these procedures to properly aggregated, seasonally adjusted employment data from the monthly Current Population Survey (CPS). Below, we briefly preview our main findings on employment changes (all in percentage terms) by occupation, industry, and MSA.

Regarding occupational employment changes, first, while job losses occur across all occupations between March and April 2020 (the crisis phase), food preparation and serving as well as personal care and service are hit the hardest. But these occupations also recoup more jobs between April and June 2020 (the partial recovery phase). Second, more generally, occupations that require more physical contact or are less amenable to remote work lose more jobs during the crisis phase, only to add more jobs back during the recovery phase. In both phases, the effects are stronger for physical proximity than for work-from-home feasibility. Third, lower-paying occupations lose more ground as the economy plunges into crisis, but also regain more ground as the economy starts to recover; these effects are most obvious for occupations in the bottom quartile of the occupational mean wage distribution. Compared to the COVID-19 pandemic, the Great Recession adversely affects different occupation groups (notably, construction workers) and do not give rise to similar patterns of occupational employment changes across the wage distribution.

Concerning industrial employment changes, first, employment in personal services, entertainment and recreation services, and retail trade decrease the most during the crisis phase, although no sectors are left unharmed. During the partial recovery phase, personal services and retail trade add the most jobs back whereas entertainment and recreation services continue to lose jobs. Unsurprisingly, the industry groups most subjected to the COVID-19 pandemic differ from those most negatively affected by the Great Recession. Second, essentialness shields industries from severe job losses as the pandemic hits: Employment in essential industries decreases by less than employment in non-essential industries. Yet again, non-essential industries recoup more jobs as the economy trudges back to normal.

Having demonstrated that overall employment changes vary with occupational and industrial vulnerability to the pandemic, we next investigate if regional variations in occupational and industrial compositions contribute to regional variations in employment changes. During the crisis phase, physical proximity seems to matter more to MSA employment changes than work-from-home capability. On average, an MSA with a higher pre-COVID-19 fraction of workers employed in high-physical-proximity occupations sustains a larger decline in total employment between March and April 2020. However, as the economy recovers, the higher the pre-COVID-19 fraction of workers employed in low-work-from-home occupations within essential industries, the more jobs are added back in the MSA. Finally, we zoom in on sectoral employment changes at the MSA level. During the crisis phase, the higher the pre-COVID-19 fraction of workers employed in occupations that require high interpersonal contact or are less suited to remote work, the starker the drop in manufacturing employment in the MSA. By contrast, during the same phase, the employment change in broad services in an MSA is only (negatively) correlated with the pre-COVID-19 fraction of workers in occupations with high physical proximity.

Related literature. The literature on the impacts of the COVID-19 pandemic and the subsequent government responses on the labor market is rapidly expanding as the crisis evolves. Studies that look at the early stage of the pandemic have documented various challenges that the COVID-19 shock poses to firms, especially small businesses. Business closings and hiring freezes are widespread (Bartik, Bertrand, Cullen, et al. (2020), Fairlie (2020b); Campello, Kankanhalli, and Muthukrishnan (2020), Kahn, Lange, and Wiczer (2020)). Amidst mounting uncertainty, households have also tightened their belts (Bachas et al. (2020), Coibion, Gorodnichenko, and Weber (2020a)). As firms and households struggle to cope with the crisis, unsurprisingly, at the outset, unemployment sharply increases while hours worked and labor force participation declines (Coibion, Gorodnichenko, and Weber (2020b), Cowan (2020)). These negative effects stem in large part from the public health risks of the coronavirus, but also result from firm and household responses to government shelter-in-place and social distancing policies (Gupta et al. (2020), Rojas et al. (2020)).

Not only do firms and workers adjust to stay-at-home and social distancing orders, but they also respond to government reopening plans and fiscal stimulus (e.g., the CARES Act). After the low point in April, partial recovery has generally followed state reopening. The speed of recovery varies across states: states with more small business loans from the Paycheck Protection Program (PPP) or with more generous UI benefits see faster rebounds in employment and spending (Bartik, Cullen, Glaeser, Luca, Stanton, and Sunderam (2020), Casado et al. (2020)). However, as PPP bureaucracy disfavors small businesses (Neilson, Humphries, and Ulyssea (2020)) and uncertainty about the reopening of related businesses causes firms to delay their own reopening (Balla-Elliott, Cullen, Glaeser, Luca, and Stanton (2020)), recovery is at best a slow process. Our analysis compares employment changes during the initial shock and during the later partial recovery, adding to the smaller number of papers that track the economic impacts of the COVID-19 pandemic beyond the shock stage (Bartik, Bertrand, Lin, Rothstein, and Unrath (2020), Fairlie (2020a)).

Apart from quantifying the overall effects on employment and business survival, previous studies have found significant heterogeneity in response to the COVID-19 crisis across occupations. As mentioned earlier, occupations differ in their suitability for remote work and requirement for interpersonal contact. Thus, the pandemic may induce different employment changes across occupations along these dimensions. The existing evidence on such occupational heterogeneity is mixed and likely needs updating as the crisis unfolds. Using CPS data, Montenovo et al. (2020) find that occupations that require more interpersonal contact and are less amenable to remote work sustain more severe job losses between February and April 2020. Kahn et al. (2020) reach the same conclusion with UI claims data from select states, but highlight that vacancy postings on Burning Glass Technologies are lower in March for occupations with *higher* work-from-home capability. This depressed labor demand suggests that while these occupations are less affected on impact, they may also make a slower comeback afterward. Our work extends Montenovo et al. (2020)'s analysis to include the partial recovery and confirms, with data on realized employment, Kahn et al. (2020)'s vacancy-based prediction.

The negative impacts of the COVID-19 pandemic is not equally felt across the occupational earnings distribution. Using administrative payroll data, Cajner et al. (2020) report that from February to April 2020, workers in the bottom quintile of the wage distribution see employment drop by 35%. By contrast, the magnitude of this drop is only 9% for those in the top quintile. This echoes the finding in Papanikolaou and Schmidt (2020) with CPS data that lower-paying workers are more adversely affected by the COVID-19 shock. As a departure from these early studies, our paper: (i) tracks employment changes along the occupational wage distribution, instead of the individual earnings distribution, (ii) compares these changes by occupational work-from-home feasibility and physical proximity, and (iii) traces the evolution of employment changes during the initial shock and during the partial recovery.

Just as occupations can vary in their sensitivity to the negative impacts of the COVID-19 pandemic, employment in different sectors or industries can be differently affected. Classifying industries into essential or non-essential based on the 'New York State on PAUSE' executive order, Kahn et al. (2020) document that from March to April 2020, except for essential retail and nursing (the "front-line" jobs most in-demand), all industries experience reductions in job postings and spikes in UI claims, independently from their essential status. Papanikolaou and Schmidt (2020) instead measure the vulnerability of a sector to the COVID-19 crisis by the fraction of its workforce that is not able to work remotely. One of their findings is that sectors for which this fraction is higher see larger contractions in employment between March and April 2020. In contrast to Kahn et al. (2020) and Papanikolaou and Schmidt (2020), Bartik, Bertrand, Lin, et al. (2020) do not dissect industries by essentialness or COVID-19 sensitivity, but group them into broad sectors to discover that low-wage services, especially the retail and leisure and hospitality sectors, drive the employment decline in March 2020.

In short, while existing papers have analyzed the heterogenous responses in employment separately by occupation, industry, and earnings level, or by some pairwise combination of these, our paper interweaves all these layers within a "before-and-after" framework to study movements in the labor market both when the shock hits and when the economy rebounds. Most importantly, informed by our results for occupations and industries, we hypothesize that regional differentials in occupational and industrial compositions can explain regional variations in employment changes during the course of the COVID-19 pandemic. Unlike previous research that examine variations across states or counties (e.g., Desmet and Wacziarg (2020)), given our interest in the implications of the COVID-19 crisis for local employment, we choose to focus on MSAs. An MSA, by virtue of being socio-economically integrated, is a reasonable approximation of a local labor market.

The remainder of the paper is organized as follows. Section 2 describes the data and the construction of the primary variables. Sections 3, 4, and 5 discuss the results on employment changes by occupation, industry, and MSA, respectively. Finally, Section 6 concludes.

2 Data description

Our empirical analysis draws on data from several sources.

Employment data. From the monthly Current Population Survey (CPS), we extract only those observations located in an MSA between January 2000 and June 2020. We next aggregate monthly employment by occupation, industry, and MSA. For each of the three resulting panels, we use X-13ARIMA-SEATS, the seasonal adjustment software developed by the US Census Bureau, to deseasonalize employment at the monthly frequency. In addition to aggregating employment by detailed occupation, we further pool employment by occupation group according to the US Census Bureau's occupation grouping convention.[1] Likewise, apart from aggregating employment by detailed industry, we tally employment by sector: manufacturing and broad services.[2] We seasonally adjust the resulting sectoral employment panels with the same aforementioned method.

Industry essentialness. Using the 1990 industry classification in the CPS, we categorize industries as essential or non-essential in close accordance with Montenovo et al. (2020). These authors

[1] https://www.bls.gov/cps/cpsoccind.htm

[2] The manufacturing sector comprises all manufacturing industries. The broad services sector consists of: business and repair services; entertainment and recreation services; personal services; professional and related services; transportation, communication, and other public utilities; finance, insurance, and real estate; retail trade; and wholesale trade.

assign essential status to NAICS 2017 three-digit industry codes according to the US Department of Homeland Security (2020)'s guidance on identification of critical industries during the COVID-19 response. We map these NAICS 2017 three-digit industry codes to CPS three-digit industry codes. Table A2 in Appendix A lists those industries classified as essential.

Occupational COVID-19 sensitivity. Following Mongey et al. (2020), we characterize occupations by their work-from-home (WFH) potential and physical proximity (PP). Using the most recent (2018-2019) data from the O*NET database, the CPS, and the Bureau of Labor Statistics (BLS) Occupational Employment Statistics (OES), Mongey et al. (2020) construct two continuous measures of occupational vulnerability to the negative economic impact of the COVID-19 pandemic: low work-from-home (LWFH) and high physical-proximity (HPP). These indices are constructed based on different sets of O*NET survey questions meant to capture different aspects of an occupation,[3] hence, should be interpreted as complements rather than substitutes.[4]

Part of our analysis further reduces Mongey et al. (2020)'s continuous LWFH and HPP measures to factor variables with two values: low (L) and high (H). An occupation is classified as LWFH (HWFH) if its continuous LWFH index is equal to or above (below) the median value of the same index across all occupations. An occupation is classified as HPP or LPP in a similar manner.

MSA industrial and occupational compositions. For each MSA, we calculate: (i) the proportion of workers employed in manufacturing or broad services, (ii) the proportion of workers employed in essential or non-essential industries, and (iii) the fraction of workers employed in LWFH or HPP occupations, all in 2019. To explore the interaction between occupational and industrial sensitivity to the negative consequences of the COVID-19 pandemic, we also compute the MSA's pre-crisis fraction of workers employed in the four categories defined by essentialness and WFH/PP: {Essential, LWFH}, {Essential, HPP}, {Non-essential, LWFH}, and {Non-essential, HPP}.

Other data. The remaining components of our data are: occupational annual wages from the

[3]The WFH feasibility is determined based on 17 O*NET survey questions, including for example: "How frequently does your current job require electronic mail?" (Module *Work Context*, Q4); "How often does your current job require you to work outdoors, exposed to all weather conditions?" (Module *Work Context*, Q17). By contrast, the PP measure only depends on one O*NET survey question, namely: "How physically close to other people are you when you perform your current job?" (Module *Work Context*, Q21).

[4]Examples of occupations that are LWFH but not HPP: cabinetmakers and bench carpenters, logging workers, and machinists. Examples of occupations that are HPP but not LWFH: childcare workers, telemarketers, and telephone operators.

OES, MSA annual unemployment rates from the BLS Local Area Employment Statistics, MSA annual median household income from the American Community Survey, and MSA annual population estimates from the US Census Bureau.

Timing of crisis and recovery. Much of the analysis that follows is centered on two periods: (i) the first four months of the COVID-19 pandemic (March-June 2020), and for comparison, (ii) the three years encompassing the Great Recession (December 2007-December 2010). Each period is further broken down into two phases: crisis and recovery. Although COVID-19 pandemic is still ongoing, given the currently available data, we refer to March-April 2020 as the crisis phase and April-June 2020 loosely as the recovery phase (more on this in Section 3). According to the National Bureau of Economic Research (NBER)'s business cycle table, December 2007 and June 2009 are the peak and the trough of the 2007-2009 financial crisis, respectively. For the Great Recession, therefore, we designate December 2007-June 2009 as the crisis phase and June 2009-December 2010, comparable in length to December 2007-June 2009, as the recovery phase.[5]

3 Occupational employment changes

3.1 Overall occupational employment changes

Event-study regression. We run the following event-study regression to test for pre-trends and investigate the dynamic effect on employment at the occupation level since the outbreak of the COVID-19 pandemic:

$$\log(\text{Employment})_{j,t} = \alpha_j + \gamma_{-5}\mathbb{1}\{K_t \leq -5\} + \sum_{k=-4}^{4} \gamma_k \mathbb{1}\{K_t = k\} + \epsilon_{j,t} \tag{1}$$

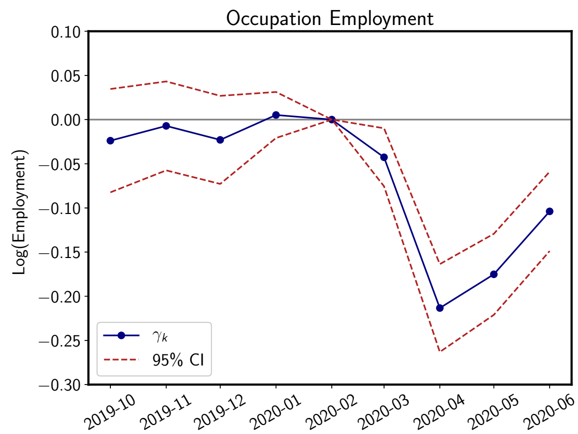
where $\log(\text{Employment})_{j,t}$ is occupation j's log employment in month t; α_j is occupation fixed effects; K_t is the relative month to the outbreak of the pandemic. To address seasonality concerns, throughout our analysis, we seasonally adjust employment at the monthly frequency as described in Section 2. In the US, the pandemic breaks out in March 2020. Therefore, we use February 2020 as the base month for comparison (i.e., $K_t = 0$ when t is February 2020) and normalize the coefficient

[5] Another reason for selecting December 2010 to close off the comparison recovery phase is that by this date, the US real gross domestic product has generally returned to its pre-crisis level (FRED® Economic Data).

for February 2020 to zero.

Figure 1 plots the coefficients γ_k from estimating Equation 1. For the months prior to the pandemic, the coefficients are not significantly different from zero at the 5% level, suggesting that there is no pre-trend. However, as the crisis hits in March 2020, employment declines by 21% in April relative to February. From the April trough, by June, employment has climbed up by 11%.

Figure 1 Occupational employment in months surrounding the COVID-19 pandemic

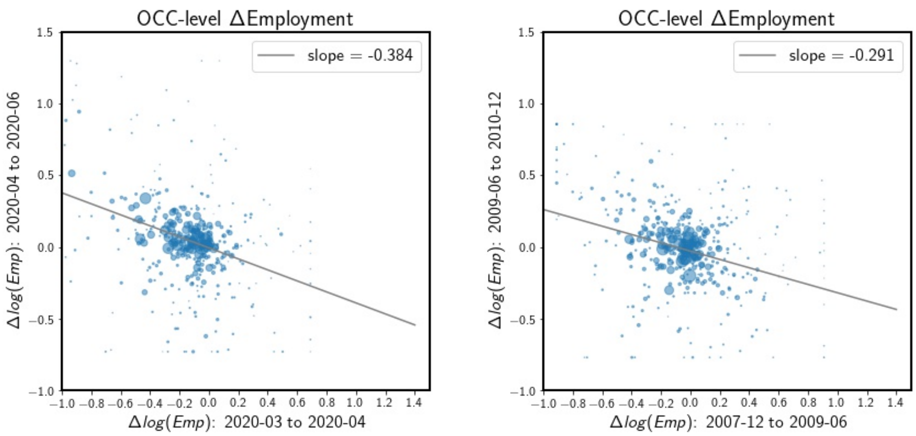


Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Standard errors are clustered at the occupation level.

Crisis vs Recovery. We next examine occupational employment changes by sub-period. Based on the event-study results in Figure 1 above, we define March-April 2020 as the crisis phase and April-June 2020 as the recovery phase for the COVID-19 pandemic. We first look at employment changes by detailed occupation and then employment changes by broad occupation category. In both steps, we compare the COVID-19 pandemic to the Great Recession.

Employment changes by detailed occupation. Figure 2(a) plots the log changes in employment for 407 detailed occupations over the crisis phase and the recovery phase. We weight the scatter points by occupational employment share in March 2020. The average employment decline in the crisis phase of the COVID-19 pandemic is 18%, dwarfing the 3% average job loss over the much longer 18-month window that constitutes the crisis phase of the Great Recession. While the pandemic sees a greater decline in employment, the recovery is also faster and of a greater degree than the Great Recession. The slopes of the fitted lines in figures 2(a) and 2(b) indicate that on average, for every 10% decrease in employment for an occupation, employment recovers by 3.84% in the recovery phase of the COVID-19 pandemic and by 2.91% during that of the Great Recession.

FIGURE 2 Occupation employment change: COVID-19 pandemic vs Great Recession



(a) COVID-19 Pandemic (b) Great Recession

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. Each panel covers 407 occupations. The scatter points are weighted by the occupation's employment share in March 2020 (panel (a)) and December 2007 (panel (b)).

Employment changes by broad occupation. For Census 2010, the US Census Bureau classifies 535 detailed occupations into 22 broad occupation categories. Figure 3 plots the employment changes for each such broad occupation category. Over March-April 2020, job losses are particularly severe for Food preparation and serving related occupations (-61%) as well as Personal care and service (-42%).[6] All broad occupation categories experience at least a 3% decline in employment, except for Computer and mathematical with a net increase of 2%. To put these into perspective, the Great Recession has a starkly different impact on occupational employment. In percentage terms, job losses are smaller: a 26% drop in employment makes Construction and extraction the hardest-hit occupation; Production comes second with a 23% decline. Another striking difference is that seven out of 22 occupations experience an increase in employment during the crisis phase.

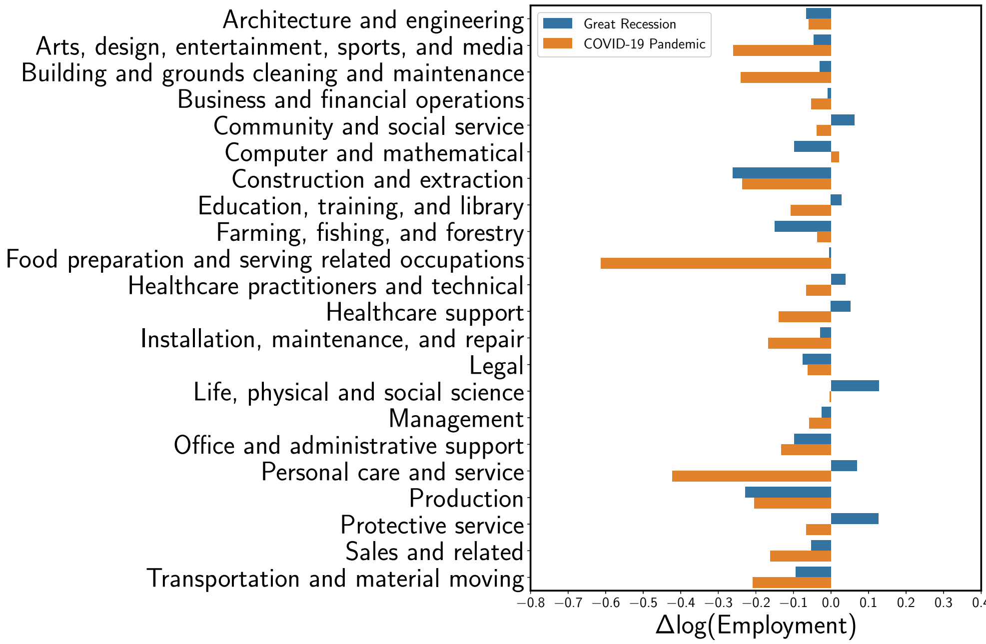
Moving to the recovery phase, most occupations that are hit harder during March-April 2020

[6]The other hard-hit broad occupation categories are: Arts, design, entertainment, sports, and media; Building and grounds cleaning and maintenance; Construction and extraction; Transportation and material moving; Production; Installation, maintenance, and repair; and Sales and related.

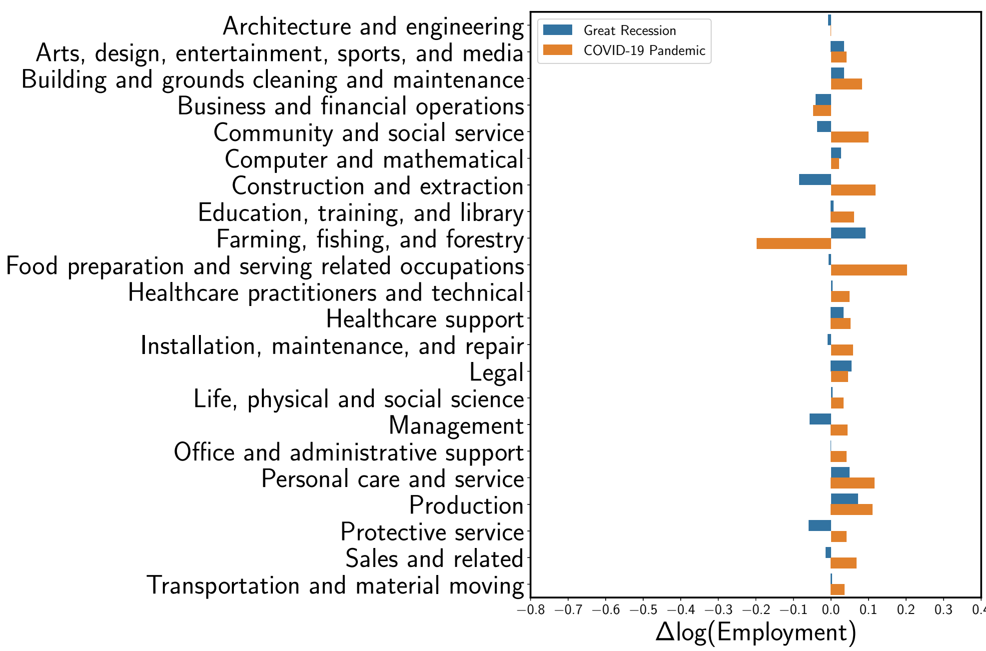
have a larger rebound. For example, the Crisis vs Recovery net change is (−61%, 20%) for Food preparation and serving related occupations, (−42%, 12%) for Personal care and service, (−24%, 12%) for Construction and extraction, (−21%, 11%) for Production and (−16%, 6%) for Sales and related. Noticeably, Transportation and material moving and Arts, design, entertainment, sports, and media are two occupations that sustain severe (more than 20%) job losses, but do not recoupe much (4%).

Comparing occupational employment changes in the COVID-19 pandemic to the Great Recession, three major differences stand out. First, the COVID-19 pandemic is characterized by broader and steeper employment drops, while seven out of 22 broad occupations are spared from job losses during the crisis phase of the Great Recession. Second, there is a negative correlation (−0.296) in employment changes between the crisis phase and the recovery phase of the COVID-19 pandemic, while the equivalent correlation is roughly zero for the Great Recession (see Appendix Figure B1). This suggests that on average, broad occupation categories with a 10% job loss over the crisis phase have a net employment increase of 3% over the recovery phase for the COVID-19 crisis. However, broad occupations that experience greater job losses do not necessarily recover more after the Great Recession. A possible reason is that the Great Recession spans a longer period and induces structural changes in the economy so that some jobs are lost permanently while others survive the downturn. Third, occupations that are hit hardest differ by crisis. The sustained shrinkage of Construction and extraction is a hallmark of the Great Recession as its root cause is a housing crisis. By contrast, the COVID-19 pandemic hits occupations that face higher risks of coronavirus infection (e.g., Food preparation and serving related occupations). The fact that Computer and mathematical is the only occupation with an increase in employment could be due to increased labor demand for tech jobs as much economic activity switches from in-person to online during the pandemic.

FIGURE 3 Occupational employment changes: COVID-19 pandemic vs Great Recession



(a) Crisis phase



(b) Recovery phase

Note: The crisis phase is March-April 2020 for the COVID-19 pandemic and December 2007-June 2009 for the Great Recession. The recovery phase is April-June 2020 for the COVID-19 pandemic and June 2009-December 2010 for the Great Recession.

3.2 Employment changes by occupational vulnerability

The COVID-19 pandemic is first and foremost a public health crisis. The coronavirus spreads primarily from person to person; the main channel of transmission is through respiratory droplets produced when an infected person coughs, sneezes, or talks (Centers for Disease Control and Prevention (2020)). This makes the economic crisis induced by the COVID-19 pandemic to differ starkly in nature to recent economic crises. Salient examples include the Great Recession whose root cause resides in the subprime mortgages market and the financial system and the 2001 Recession that came about because of the burst of dot-com bubble. Therefore, instead of looking at leverage/frictions in the financial system or irrationality that can lead to a bubble as in studies of these previous crises, we analyze how the public health threat posed by the coronavirus spread impacts economic activity. Specifically, this section investigates the effect of occupational vulnerability to COVID-19 infection risk on employment changes.

As mentioned in Section 2, we use two continuous measures to measure this occupational vulnerability: high physical proximity (HPP) and low work-from-home (LWFH), both due to Mongey et al. (2020). We run the following regression, separately for the crisis phase and the recovery phase, to examine how employment changes vary with occupational vulnerability over the course of the pandemic:

$$\Delta \log(\text{Employment})_j^T = \alpha + \beta \, \text{Vulnerability}_j + X_j + \epsilon_j \tag{2}$$

where $\Delta \log(\text{Employment})_j^T$ is occupation j's log employment change over period T, $T \in \{$March-April 2020, April-June 2020$\}$; Vulnerability_j is occupation j's continuous measure of vulnerability (HPP, LWFH, or both); and X_j is the one-year lag of the dependent variable used as control to help address the concern that occupations may differ in their long-run employment trajectories.

Columns 1-3 of Table 1 present the results from estimating Equation 2 for the crisis phase. Occupations with higher physical proximity suffer greater employment contractions. Appendix Table A1 provides the summary statistics on the dependent variables and the regressors. The baseline estimate of the coefficient on HPP is -0.507 (Column 1 of Table 1). To put the estimate into perspective, moving from the 10^{th} to 90^{th} percentile of the distribution of the HPP index, employment declines by 24.8%.[7] Column 2 reports a coefficient of -0.197 on the LWFH index. This means that going from the 10^{th} to 90^{th} percentile of the distribution of the occupational LWFH index, employment drops by 13.2% more.[8] Column 3 shows that if we include both measures, the negative impact of HPP on employment dominates that of LWFH: The negative impact on employment of HPP is twice that of LWFH.

The gap in magnitude stems from the different dimensions along which HPP and LWFH measure the economic vulnerability of an occupation to COVID-19. As described in Section 2, the LWFH index is constructed based on a variety of O*NET survey questions, including those about the frequencies of email usage and outdoor working; whereas the HPP index is built on one O*NET survey question and measures how physically close a worker is to other people while performing their job. Given that the risk of infection is highest in close contact, it is unsurprising to see occupations with higher physical proximity sustain more job losses. By contrast, occupations with low work-from-home feasibility require people to step out of home to perform their jobs on-site. This does not necessarily imply close contact with other people at work. As a consequence, low work-from-home occupations do not incur as much job losses.

Columns 4-6 of Table 1 display the regression results for the recovery phase. Occupations with higher HPP or LWFH rebound to a greater extent, perhaps reflecting the fact that there is more lost ground to recover. However, the magnitude of the recovery pales in comparison to the amount of losses over the crisis phase.

[7]See Panel B of Appendix Table A1: $-0.507 \times (0.81 - 0.32) = -0.248$, where 0.81 and 0.32 are the 90^{th} and 10^{th} percentile of the HPP index, respectively.

[8]See Panel B of Appendix Table A1: $-0.197 \times (0.67 - 0) = -0.132$, where 0.67 and 0 are the 90^{th} and 10^{th} percentile of the LWFH index, respectively.

Table 1 Occupational employment changes by vulnerability to COVID-19

Δ Log(Employment)	03-2020 to 04-2020			04-2020 to 06-2020		
	(1)	(2)	(3)	(4)	(5)	(6)
High physical proximity (HPP)	-0.507***		-0.466***	0.221**		0.175
	(0.103)		(0.111)	(0.105)		(0.111)
Low work-from-home (LWFH)		-0.197***	-0.107		0.152*	0.118
		(0.065)	(0.069)		(0.079)	(0.083)
Δ Log(Employment): 03-2019 to 04-2019	0.084	0.060	0.077			
	(0.110)	(0.112)	(0.110)			
Δ Log(Employment): 04-2019 to 06-2019				-0.087	-0.101	-0.092
				(0.101)	(0.101)	(0.101)
Constant	0.095*	-0.123***	0.103*	-0.029	0.047*	-0.038
	(0.055)	(0.023)	(0.054)	(0.060)	(0.027)	(0.059)
Number of Occupations	389	389	389	389	389	389
R^2	0.066	0.021	0.072	0.016	0.015	0.022

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.01$).

3.3 Employment changes across occupational wage distribution

To delve deeper, this section documents the patterns of employment changes across the occupational wage distribution during the crisis and recovery phases of the COVID-19 pandemic and compares them to their Great Recession counterparts. Figure 4 plots the smoothed log changes in employment by occupational wage percentile for the two periods. As evident in Figure 4(a), while employment drops across the board during the COVID-19 crisis, lower-paying occupations sustain much greater job losses in percentage terms. Employment for the occupations in the bottom quartile of the 2018 occupational annual wage distribution decreases by at least 20% and as much as 60% in the span of a month. Job losses for occupations in the interquartile of the same wage distribution are similar in magnitude at around 20%. Employment in the highest-paying occupations is much less affected.

Comparing Figure 4(a) and Figure 4(c), two distinctive features of the COVID-19 crisis stand out. First, employment changes between March and April 2020 are negative and largely monotone: the lower-paying an occupation, the more job losses. This monotonicity is absent between

December 2007 and June 2009: occupations at the lower end of the contemporary wage distribution suffer less job losses in percentage terms than those in the lower middle range of the same wage distribution. In addition, employment in occupations in the top quartile of this wage distribution actually increases. Second, across the wage distribution, the maximum extent of occupational job losses during the 18 months of the Great Recession is about 15%—much smaller than occupational job losses just in the first month of the COVID-19 pandemic.

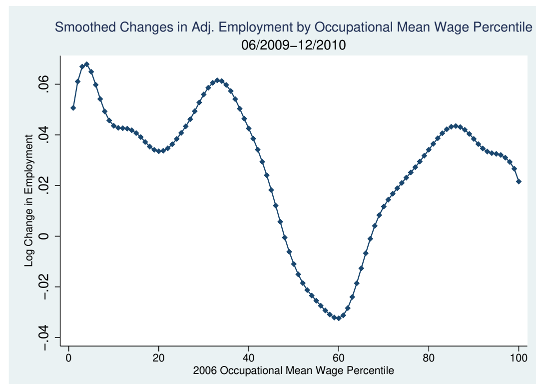
Shifting focus to the recovery phase, the pattern in Figure 4(b) is opposite to that in Figure 4(a). Lower-paying occupations sustain the most severe employment drops between March and April 2020, but also make a stronger rebound. The reverse monotonicity in Figure 4(b) partly reflects the fact that harder-hit occupations *ipso facto* have more lost ground to recover. However, even the lowest-paying occupations only add about 20% more jobs in June relative to April. This improvement pales in comparison with the dramatic drop between March and April, implying a sluggish recovery. Finally, the same qualitative observations from the comparison for the crisis phase between the COVID-19 pandemic and the Great Recession apply to the recovery phase: The percentage job gains in the first 18 months after the Great Recession are smaller and the pattern of job gains across the occupational wage distribution in Figure 4(d) lacks the monotonicity manifested in Figure 4(b).

FIGURE 4 Smoothed log changes in adjusted employment

(a) COVID-19: Crisis

(b) COVID-19: Recovery

(c) Great Recession: Crisis



(d) Great Recession: Recovery

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Within each period, log changes in employment are winsorized at the top and bottom 2.5% and Lowess-smoothed with a bandwidth of 0.4.

Figure 5 plots the smoothed log changes in employment during the COVID-19 pandemic by occupational wage percentile, separately for occupations more and less susceptible to COVID-19 infection risk.[9] As described in Section 2, the two measures of occupational sensitivity to COVID-19 are work-from-home (WFH) and physical proximity (PP) and the two categorical levels associated with them are low (L) and high (H). An occupation is regarded as higher-risk if it is characterized by LWFH or HPP. Consistent with the regression results in Section 3, Figure 5(a) and Figure 5(c) together suggest that during the crisis phase, physical proximity influences occupational job losses more than work-from-home capability: While LWFH and HWFH occupations experience similar

[9] To facilitate comparison with Figure 4, the run variable in Figure 5 is relative to the overall occupational wage distribution in the reference year. We do not re-rank occupations within each characteristic group.

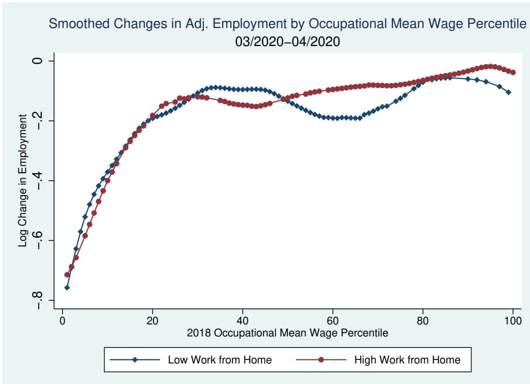
percentage drops in employment across the board, HPP occupations lose more jobs than LPP occupations. On a related note, the magnitude of job losses in these figures echoes that in Figure 4(a). So does the monotonicity in job losses by occupational percentile.

Looking ahead to the recovery phase, recall from Figure 4(b) that between April and June 2020, the most noticeable turnaround occurs at the lower end of the occupational wage distribution. Figure 5(b) additionally shows that at this lower end of the wage distribution, LWFH occupations regain more jobs than HWFH occupations. For each type of occupation—LWFH or HWFH—the extent of recoupment decreases with the wage percentile. However, there is no consistently ordered relationship in the rate of recovery across the wage distribution between LWFH and HWFH occupations.

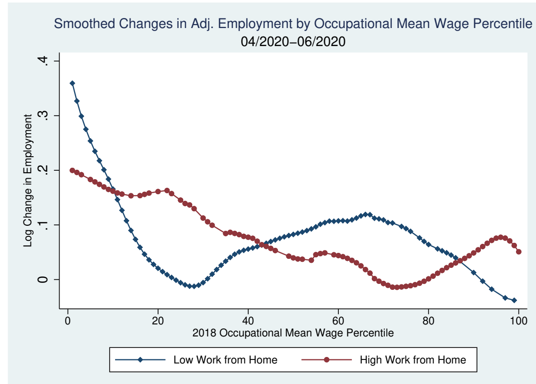
Both LWFH and HPP occupations are expected to be negatively affected by the COVID-19 pandemic. However, the impact may not be equally felt across these two occupational characteristics. Consequently, the rate of recovery can differ between them. Indeed, in contrast to Figure 5(b), Figure 5(d) indicates that among lower-paying occupations, LPP occupations recover better than HPP occupations, although it is the latter that suffers greater damage in the crisis phase. One possible explanation for why LWFH occupations make a better comeback after the April nosedive than HPP occupations is the partial rollback of state stay-at-home orders starting in May. Lifting the lockdown could allow individuals employed in LWFH occupations to leave home and return to work. However, it may not enable those in HPP occupations to resume working since close proximity raises the risk of coronavirus infection.

As a placebo check, Appendix Figure B2 provides the equivalent of Figure 5 for the Great Recession. Since the Great Recession is starkly different in nature from the COVID-19 pandemic, we do not expect the WFH and PP occupational characteristics to inform job losses (gains) during the Great Recession (the subsequent recovery). Reassuringly, the occupational employment changes captured in Figure B2 do not appear to operate along the WFH/PP line. Neither does this figure show any clear patterns across the relevant occupational wage distribution.

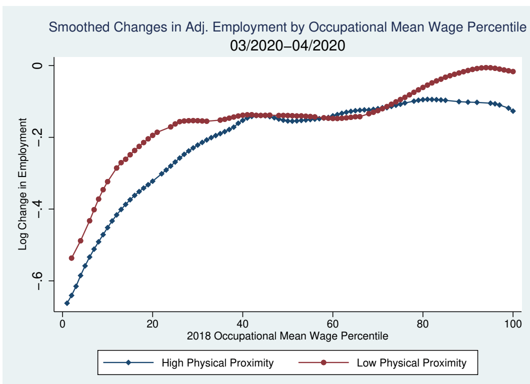
Figure 5 COVID-19: Smoothed log changes in adjusted employment by WFH/HPP



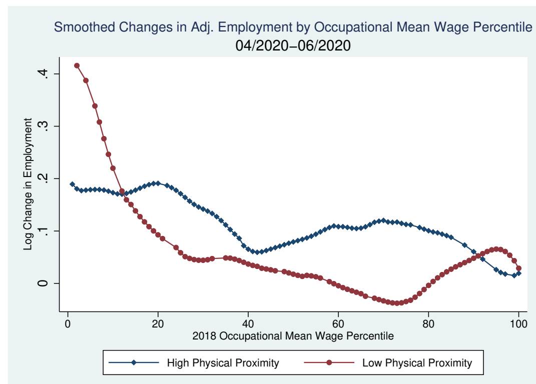
(a) COVID-19: Crisis—WFH



(b) COVID-19: Recovery—WFH



(c) COVID-19: Crisis—PP



(d) COVID-19: Recovery—PP

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Within each period, log changes in employment are winsorized at the top and bottom 2.5% and Lowess-smoothed with a bandwidth of 0.4.

4 Industrial employment changes

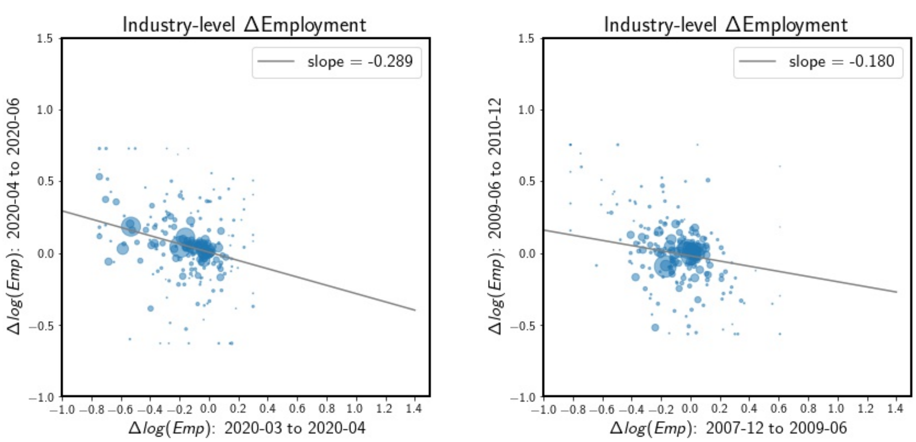
4.1 Overall industrial employment changes

Using an event study similar to Equation 1, we estimate that at the industry level, employment plunges by 16% over February-April 2020 and recovers by 6% over April-June 2020 (see Appendix Figure B3).

Crisis vs Recovery. Analogous to our analysis on occupational employment changes, this section documents employment changes at the industry level over the crisis and the recovery phase (as previously defined). We start with employment changes by detailed industry before examining employment changes by sector. In both steps, we compare the COVID-19 pandemic to the Great Recession.

Employment changes by detailed industry. Figure 6(a) plots the log changes in employment at the industry level during the crisis phase and the recovery phase. We weight the scatter points by industry employment share in March 2020. The mean of industry employment decline in the crisis phase of the COVID-19 pandemic is 15%, dominating the 9% average job loss over the much longer 18-month window that delimits the crisis phase of the Great Recession. Reminiscent of our findings on occupational employment, while the pandemic sees larger declines in employment across industries, the recovery is also faster and larger than what follows the Great Recession. The slopes of the fitted line in figures 6(a) and 6(b) imply that on average, for every 10% decrease in employment for an industry, employment increases on net by 2.89% in the recovery phase of the COVID-19 pandemic and by 1.80% during that of the Great Recession.

FIGURE 6 Industrial employment changes: COVID-19 pandemic vs Great Recession



(a) COVID-19 Pandemic (b) Great Recession

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. Each panel covers 217 industries. The scatter points are weighted by the industry's employment share in March 2020 (panel (a)) and December 2007 (panel (b)).

Employment changes by sector. We next explore the heterogeneity in employment contraction at the sector level. The 237 detailed industries (according to the the 1990 industry classification in the

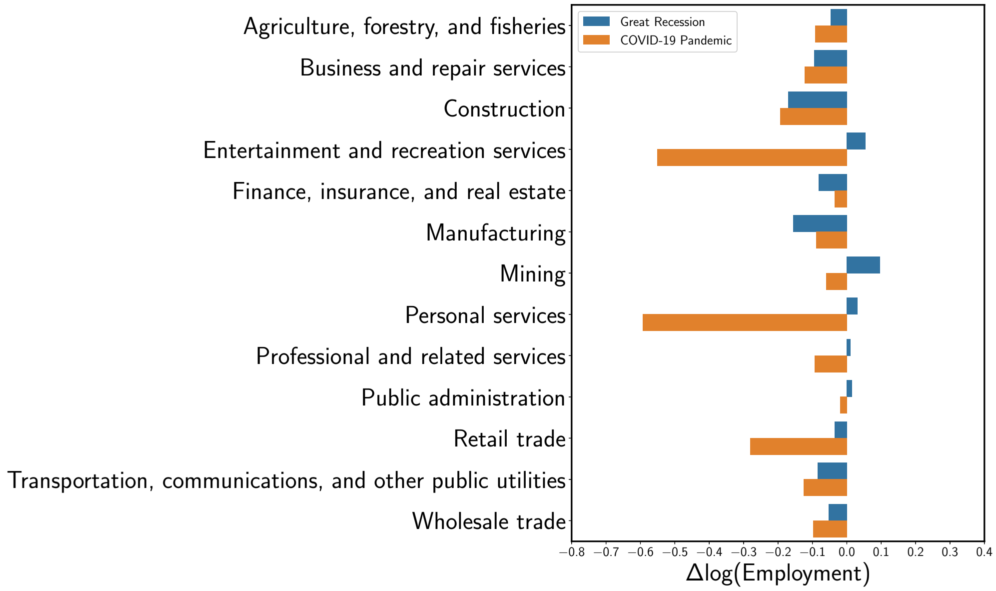
CPS) fall into 13 sectors.[10] Figure 7 plots employment changes by sector. The crisis hits across the board, but the sectoral responses are heterogeneous: The net employment change ranges from −2% to −59%. Personal services comes first with a 59% employment contraction, followed by Entertainment and recreation services with a 55% decline. Retail trade (−28%) and Construction (−19%) comprise the second-tier hard-hit sectors. Public administration (−2%) and Finance, insurance, and real estate (−4%) are the least harmed.

Most sectors have yet to see significant recovery. The recovery concentrates in Personal services (+21%); Retail trade (+13%); and Professional and related services (+6%). Even these seemingly large comebacks are less than 50% of what has been lost over the crisis phase (the only exception is Professional and related services). Another noticeable fact emerges: several industries contract substantially but barely rebound (e.g., Transportation, communications, and other public utilities, Wholesale trade and Manufacturing).

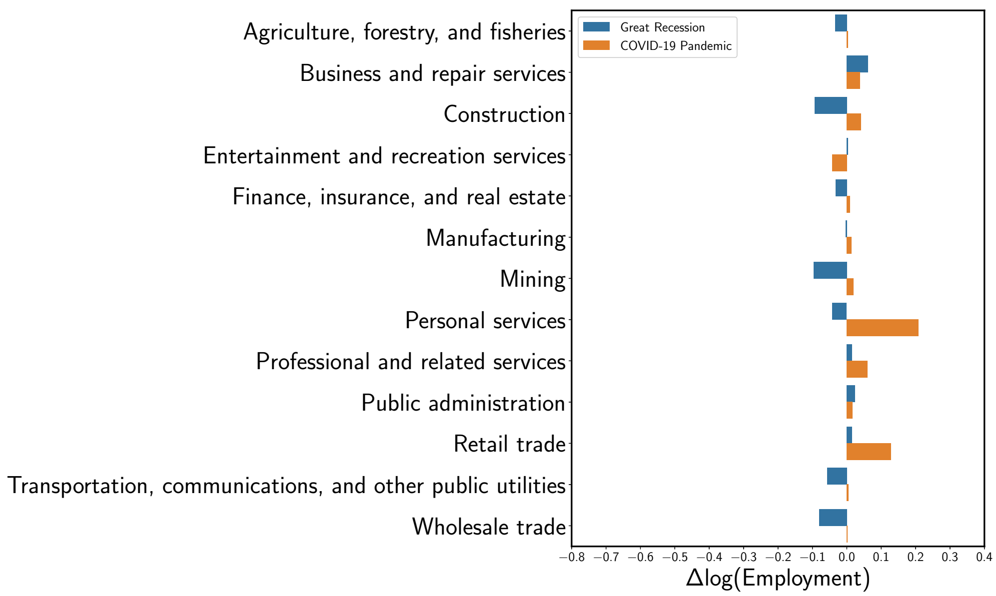
At the sector level, employment changes during the COVID-19 pandemic also differ from those during the Great Recession. First, the COVID-19 pandemic hit all sectors across the board and hit harder, while five out of 13 sectors are spared from job losses during the Great Recession. Second, the correlation in employment changes between the crisis phase and the recovery phase is negative (−0.222) for the COVID-19 pandemic but positive (+0.262) for the Great Recession (see Appendix Figure B4). This means that for the COVID-19 pandemic, on average, sectors that contract more in the crisis phase recover more. By contrast, for the Great Recession, sectors that contract in the crisis phase continue to shrink in the recovery phase. One possible explanation is that after the Great Recession introduces structural changes to the economy: some sectors permanently shrink while others expand. Third, the hard-hit sectors differ by crisis. The hallmark of the Great Recession is the continued shrinkage of Construction and Finance, insurance, and real estate. This is not surprising as the Great Recession involves a housing crisis and a financial meltdown due to subprime mortgages. On the other hand, given its nature as a public health crisis, the COVID-19 pandemic hurts Personal services, Entertainment and recreation services and Retail trade the most.

[10] We exclude the Active duty military sector.

Figure 7 Sectoral employment changes: COVID-19 pandemic vs Great Recession



(a) Crisis phase



(b) Recovery phase

Note: The crisis phase is March-April 2020 for the COVID-19 pandemic and December 2007-June 2009 for the Great Recession. The recovery phase is April-June 2020 for the COVID-19 pandemic and June 2009-December 2010 for the Great Recession.

4.2 Employment changes by industrial essentialness

Certain industries are categorized as essential so that they are exempted from the "shelter-in-place" orders issued by state governments. We examine whether being essential affect industry-level employment change using the regression:

$$\Delta \log(\text{Employment})_i^T = \alpha + \beta\, \mathbb{1}\{Essential\}_i + X_i + \epsilon_i \tag{3}$$

We run this regression separately for the crisis phase and the recovery phase. $\Delta \log(\text{Employment})_i^T$ is industry i's log change in employment over period T, $T \in$ {March-April 2020, April-June 2020}; X_i is the one-year lag of the dependent variable used as control to mitigate the concern that industries may differ in their long-term employment trajectories; $\mathbb{1}\{Essential\}_i = 1$ if the industry i is considered essential, otherwise it is equal to zero. Appendix Table A3 provides the summary statistics on the dependent variables and regressors.

Column 1 of Table 2 presents the results from estimating Equation 3 for the crisis phase. Employment in essential industries contracts less. Our estimated coefficient on the essential dummy suggests that compared to non-essential industries, essential industries sustain 20.1% less job losses over the crisis phase. Column 2 of Table 2 presents the regression results for the recovery phase. Compared to non-essential industries, essential industries add back 9.3% less jobs during the recovery phase. Taken together, our results show that at the industry level, essential industries sustain a significantly smaller contraction in the crisis phase while non-essential industries recover better than essential industries in the recovery phase.

Table 2 Industrial employment changes by essentialness

Δ Log(Employment)	03-2020 to 04-2020	04-2020 to 06-2020
	(1)	(2)
$\mathbb{1}\{Essential\}$	0.201***	-0.093**
	(0.045)	(0.044)
Δ Log(Employment): 03-2019 to 04-2019	0.100	
	(0.140)	
Δ Log(Employment): 04-2019 to 06-2019		0.044
		(0.126)
Constant	-0.302***	0.126***
	(0.043)	(0.038)
Number of industries	217	217
R^2	0.128	0.024

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. Robust standard errors are in parentheses. Significance levels: ** ($p < 0.05$), *** ($p < 0.01$)

5 MSA employment changes

5.1 MSA total employment changes

Crisis vs Recovery. This section analyzes the variation in employment change at the MSA level. A similar event study to Equation 1 shows that MSA-level employment on average decreases by 15% over February-April 2020 and recovers by 7% over April-June 2020 (Appendix Figure B5).

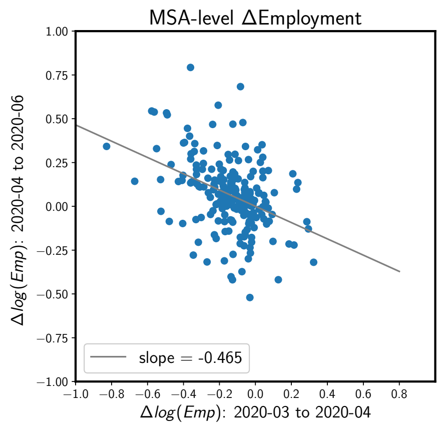
Employment change over March-April 2020 varies substantially across MSAs, ranging from -83% to $+32\%$ (see Appendix Table A4). Appendix Figure B6 projects these MSA-level employment changes on a map, separately for the crisis phase and the recovery phase. To capture the underlying employment structure, aside from employment in all sectors, we further examine the MSA-level employment within the Manufacturing sector and the Broad Services sector.[11]

Figures 8(a), 8(b), and 8(c) display employment changes in all sectors, in Manufacturing, and in Broad Services, respectively. Each scatterplot shows a negative correlation in employment changes between the crisis and the recovery. On average, an MSA with 10% more job losses in all sectors

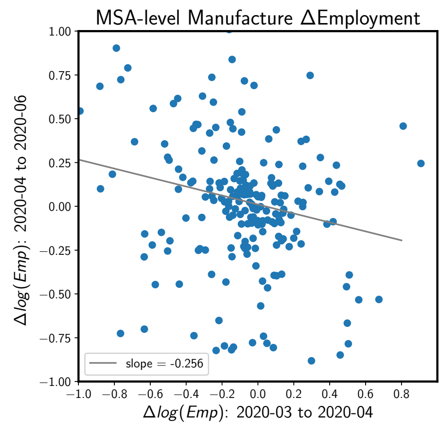
[11] Section 2 describes how we define these sectors.

in the crisis phase gains 4.65% more jobs in the recovery phase (Figure 8(a)). This quantitative relationship is also visible for changes in employment in the Broad Services sector (Figure 8(b)). In contrast, for Manufacturing employment, the average net increase is only 2.56% for every 10% contraction (Figure 8(c)). In addition, the across-MSA variation in employment change is larger for Manufacturing than for all sectors or for Broad Services.

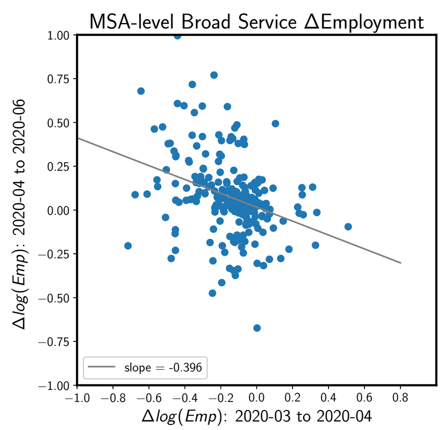
FIGURE 8 MSA employment changes: Crisis vs Recovery



(a) All sectors



(b) Manufacturing



(c) Broad Services

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method.

MSA job composition and employment changes. Our previous results show that the occupation-level employment change depends on occupational vulnerability to COVID-19 (HPP and LWFH) and the industry-level employment change depends on "essential" status. We next ask whether the underlying employment composition (i.e., the fraction of jobs in HPP/LWFH occupations or in essential industries) at the MSA level explains the across-MSA variation in employment change. To answer this question, we run the regression:

$$\Delta \log(\text{Employment})_m^T = \alpha + \beta\, \text{JobComposition}_m^{19} + X_m + \epsilon_m \tag{4}$$

where $\log(\text{Employment})_m^T$ is MSA m's log change in employment over period T, $T \in \{$March-April 2020, April-June 2020$\}$. $\text{JobComposition}_m^{19}$ is MSA m's job composition, measured by: the fraction of workers employed in {HPP occupations, LWFH occupations, essential industries, Manufacturing sector, Broad Services sector} in MSA m in 2019. X_m is MSA-level controls, including: one-year lag of the dependent variable, log of MSA population in 2019, log of MSA median household income in 2018, and MSA unemployment rate in 2019.

Table 3 presents the results from estimating Equation 4 for the crisis phase. Appendix Table A4 provides the summary statistics on the dependent variables and controls. Columns 1-2 estimate that the semi-elasticity of employment to the pre-crisis fraction of workers employed in HPP occupation is about -0.5. Using the results with controls from Column 2, an MSA that lies at the 90$^{\text{th}}$ percentile of the distribution of the fraction of workers employed in HPP occupations has employment decline by 4.84% more than an MSA at the 10$^{\text{th}}$ percentile of the same distribution.[12] Columns 3-4 report a negative relationship between the fraction of LWFH jobs and employment change, but the coefficient is smaller in magnitude and statistically insignificant at conventional confidence levels. Columns 5-6 show that the fraction of workers in essential industries is positively correlated with employment change, although the estimate is not statistically significant.

[12] See Panel B of Appendix Table A4: $-0.484 \times (0.6 - 0.5) = 0.0484$, where 0.6 and 0.5 are the 90$^{\text{th}}$ and 10$^{\text{th}}$ percentile of the across-MSA distribution of the fraction of HPP workers, respectively.

Table 3 MSA employment changes by HPP, LWFH, and Essential: Crisis

Δ Log(Employment): 2020-03 to 2020-04	(1)	(2)	(3)	(4)	(5)	(6)
% High physical proximity in 2019	-0.517**	-0.484*				
	(0.249)	(0.274)				
% Low work-from-home in 2019			-0.231	-0.189		
			(0.156)	(0.205)		
% Essential-industry employment in 2019					0.162	0.177
					(0.297)	(0.308)
Δ Log(Employment): 2019-03 to 2019-04		0.122		0.123		0.129
		(0.106)		(0.107)		(0.106)
Log(Population) in 2019		-0.012		-0.012		-0.008
		(0.009)		(0.010)		(0.010)
Log(Median household income) in 2018		0.047		0.064		0.081
		(0.077)		(0.075)		(0.072)
Unemployment rate in 2019		-0.004		-0.003		-0.006
		(0.011)		(0.011)		(0.011)
Constant	0.146	0.103	-0.031	-0.147	-0.252	-0.464
	(0.133)	(0.369)	(0.069)	(0.353)	(0.214)	(0.363)
Number of MSAs	236	236	236	236	236	236
R^2	0.016	0.033	0.007	0.026	0.001	0.024

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$).

The regression results for the recovery phase are presented in tables 4 and 5. Columns 1-4 of Table 4 show that MSAs with higher fractions of HPP or LWFH workers have a weaker recovery (though the estimates are not statistically significant). Columns 5-6 of Table 4 show that MSAs with more workers employed in essential industries have larger rebounds in employment in the recovery phase, although the estimate is statistically significant at the 10% level with controls (Column 6). Since both occupational vulnerability and industrial essentialness can affect job recovery, we further investigate finer-grained measures of MSA job composition: the fraction of workers employed in {Non-essential, HPP}, {Essential, HPP}, {Non-essential, LWFH}, and {Essential, LWFH} jobs. Table 5 displays the results on the relationship between employment recovery and these detailed measures of MSA job composition. Columns 1-2 suggest that MSAs with higher fractions of workers in {Non-essential, HPP} lag behind on employment recovery. Using the point estimate with controls, a one standard deviation increase (0.03) in the fraction of {Non-essential, HPP} workers is associated with 3.5% less job recovery.[13] The fraction of {Non-essential, LWFH} workers is also associated with weaker recovery, although the point estimates are smaller and insignificant (Columns 5-6 of Table 5). The fraction of {Essential, LWFH} workers has a positive relationship with employment recovery: A one standard deviation increase (0.06) in this fraction is associated with 2.65% - 3.7% greater recovery.[14] Lastly, we also find a positive (but insignificant) relationship between the fraction of {Essential, HPP} workers and job recovery (Columns 3-4).

Table 4 MSA-level employment change by HPP, LWFH, and Essential: Recovery

Δ Log(Employment): 04-2020 to 06-2020	(1)	(2)	(3)	(4)	(5)	(6)
% High physical proximity in 2019	-0.069	-0.049				
	(0.290)	(0.336)				
% Low work-from-home in 2019			-0.203	-0.181		
			(0.231)	(0.287)		
% Essential-industry employment in 2019					0.468	0.613*
					(0.352)	(0.363)
Δ Log(Employment): 04-2019 to 06-2019		0.205**		0.204**		0.219**
		(0.090)		(0.090)		(0.090)
Log(Population) in 2019		-0.003		-0.005		0.001
		(0.012)		(0.012)		(0.012)
Log(Median household income) in 2018		0.016		0.001		0.015
		(0.087)		(0.085)		(0.083)
Unemployment rate in 2019		-0.011		-0.009		-0.014
		(0.012)		(0.013)		(0.012)
Constant	0.101	0.105	0.154	0.236	-0.276	-0.403
	(0.156)	(0.420)	(0.102)	(0.373)	(0.253)	(0.382)
Number of MSAs	235	235	235	235	235	235
R^2	0.000	0.031	0.004	0.033	0.009	0.045

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$).

[13] See Column 2 of Table 5 and Panel B of Appendix Table A4: $-1.167 \times 0.03 = -0.035$

[14] See Columns 7-8 of Table 5 and Panel B of Appendix Table A4: $0.443 \times 0.06 = 0.0265$ and $0.617 \times 0.06 = 0.037$.

Table 5 MSA employment change by {Essential, HPP} and {Essential, LWFH}: Recovery

Δ Log(Employment): 04-2020 to 06-2020	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% {Non-essential, HPP} in 2019	-0.907	-1.167*						
	(0.624)	(0.657)						
% {Essential, HPP} in 2019			0.297	0.376				
			(0.265)	(0.356)				
% {Non-essential, LWFH} in 2019					-0.270	-0.476		
					(0.442)	(0.446)		
% {Essential, LWFH} in 2019							0.443**	0.617**
							(0.217)	(0.292)
Δ Log(Employment): 04-2019 to 06-2019		0.215**		0.211**		0.218**		0.204**
		(0.087)		(0.089)		(0.089)		(0.089)
Log(Population) in 2019		0.001		-0.007		-0.004		-0.015
		(0.013)		(0.012)		(0.012)		(0.013)
Log(Median household income) in 2018		0.026		-0.009		0.030		-0.034
		(0.084)		(0.091)		(0.082)		(0.084)
Unemployment rate in 2019		-0.017		-0.010		-0.013		-0.004
		(0.012)		(0.012)		(0.012)		(0.013)
Constant	0.145**	0.114	-0.041	0.096	0.109	0.123	-0.103	0.179
	(0.059)	(0.290)	(0.096)	(0.292)	(0.078)	(0.301)	(0.085)	(0.280)
Number of MSAs	235	235	235	235	235	235	235	235
R^2	0.014	0.053	0.005	0.037	0.002	0.038	0.017	0.051

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$).

5.2 MSA sectoral employment changes

To further explore the mechanism behind the variation in employment change across MSAs, we separately examine MSA-level employment change for two sectors: Manufacturing and Broad Services. To this end, we estimate a variant of Equation 4, where Manufacturing or Broad Services employment replaces total employment as the dependent variable.

Manufacturing employment changes. Table 6 presents the regression results for Manufacturing in the crisis phase. Appendix Table A4 provides the summary statistics on the dependent variables and controls. Both vulnerability measures, HPP and LWFH, are negatively and significantly correlated with Manufacturing employment change. According to the estimated coefficient with controls in Column 2 of Table 6, an MSA that lies at the 90$^{\text{th}}$ percentile of the across-MSA distribution of the fraction of workers employed in HPP occupations has Manufacturing employment decline by 14% more than an MSA at the 10th percentile of the same distribution.[15] Notice that this estimate (14%) is almost three times greater than the estimate for all-sector employment (4.84%). Comparing MSAs at the 10th and the 90th percentile of the distribution of the fraction of LWFH workers, we find an additional 21.2% decline in Manufacturing employment for the one at the 90th percentile.[16] It is also worth noting that there is a strong negative relationship between the pre-crisis fraction of worked in Manufacturing and the *net* Manufacturing employment change. With regards to recovery on Manufacturing jobs, MSAs with higher fractions of HPP jobs experience weaker recovery while MSAs with higher fractions of LWFH jobs experience stronger recovery. However, none of these estimates is statistically significant (Appendix Table A5).

TABLE 6 MSA-level Manufacturing employment change by HPP and LWFH: Crisis

Δ Log(Manufacturing Employment): 03-2020 to 04-2020	(1)	(2)	(3)	(4)
% High Physical Proximity in 2019	-1.065*	-1.399**		
	(0.598)	(0.690)		
% Low work-from-home in 2019			-1.386***	-1.415**
			(0.486)	(0.653)
% Essential-industry employment in 2019		-0.326		0.154
		(1.093)		(1.053)
% Manufacturing employment in 2019		-1.433***		-1.083**
		(0.503)		(0.510)
Δ Log(Manufacturing Employment): 03-2019 to 04-2019		0.056		0.054
		(0.104)		(0.106)
Log(Population) in 2019		-0.020		-0.024
		(0.025)		(0.026)
Log(Median household income) in 2018		-0.148		-0.183
		(0.166)		(0.171)
Unemployment rate in 2019		-0.023		-0.008
		(0.035)		(0.036)
Constant	0.506	2.101	0.551**	1.708
	(0.318)	(1.545)	(0.217)	(1.401)
Number of MSAs	225	224	225	224
R^2	0.011	0.063	0.040	0.072

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.01$).

[15] See Panel B of Appendix Table A4: $-1.399 \times (0.6 - 0.5) = -0.14$, where 0.6 and 0.5 are the 90th and the 10th percentile of the distribution of the fraction of HPP workers, respectively.

[16] See Column 4 of Table 6 and Panel B of Appendix Table A4: $-1.415 \times (0.53 - 0.38) = -0.212$, where 0.53 and 0.38 are the 90th and the 10th percentile of fraction of LWFH workers in MSAs, respectively.

Broad Services employment changes. Table 7 presents our results on change in Broad Services employment over the crisis phase. There is a negative relationship between the fraction of HPP workers and Broad Services employment change. Comparing MSAs at the 90$^{\text{th}}$ and 10$^{\text{th}}$ percentile of the across-MSA distribution of the fraction of HPP workers, we find an additional 6.9% decline in Broad Services employment for the MSA at the 90$^{\text{th}}$ percentile.[17] We also find a negative relationship between the fraction of LWFH workers and Broad Services employment change, though the estimates are small and statistically insignificant (Columns 3-4 in Table 7). Additionally, we note that both the pre-crisis fraction of Broad Services employment and the pre-crisis fraction of Manufacturing employment are negatively correlated with the *net* employment change in the Broad Services sector. One possible reason for this Manufacturing-Broad Services correlation is that Manufacturing sectors are upstream of some Broad Services sectors. As shown in Table 6, MSAs with higher fractions of Manufacturing jobs sustain larger contraction in Manufacturing employment. This disruption of "upstream" jobs in Manufacturing can result in losses in "downstream" jobs in Broad Services. This identifies industrial composition as one potential source for regional disparity in employment decline. Turning to the recovery phase (Appendix Table A6), our estimated coefficients on the fraction of HPP and LWFH workers are negative but statistically insignificant. Finally, a higher fraction of jobs in essential industries is associated with stronger recovery for Broad Services jobs.

[17]See Column 2 of Table 7 and Panel B of Appendix Table A4: $-0.691 \times (0.6 - 0.5) = -0.069$, where 0.6 and 0.5 are the 90$^{\text{th}}$ and the 10$^{\text{th}}$ percentile of the distribution of the fraction of HPP workers, respectively.

Table 7 MSA-level Broad Services employment change by HPP and LWFH: Crisis

Δ Log(Broad Services Employment): 03-2020 to 04-2020	(1)	(2)	(3)	(4)
% High physical proximity in 2019	-0.560*	-0.691**		
	(0.287)	(0.333)		
% Low work-from-home in 2019			-0.277	-0.342
			(0.200)	(0.324)
% Essential-industry employment in 2019		-0.223		-0.091
		(0.421)		(0.438)
% Manufacturing employment in 2019		-0.943**		-0.865*
		(0.464)		(0.468)
% Broad Services employment in 2019		-1.139**		-1.167**
		(0.554)		(0.572)
Δ Log(Broad Services Employment): 03-2019 to 04-2019		0.104		0.102
		(0.106)		(0.107)
Log(Population) in 2019		-0.008		-0.008
		(0.011)		(0.012)
Log(Median income) in 2018		-0.020		-0.001
		(0.089)		(0.093)
Unemployment rate in 2019		-0.024		-0.021
		(0.015)		(0.015)
Constant	0.153	1.627**	-0.027	1.221
	(0.154)	(0.761)	(0.089)	(0.783)
Number of MSAs	235	235	235	235
R^2	0.014	0.053	0.008	0.044

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$).

6 Conclusion

This paper first investigates the susceptibility of the labor market to the sweeping changes caused by the COVID-19 pandemic at the occupation and industry levels. We find that occupations with higher HPP and LWFH sustain larger employment contraction over March-April 2020, with the effect of HPP being almost twice as that of LWFH. Zooming in along the distribution of occupational mean wage, losses are most severe in lower-paying jobs. Breaking down employment by HPP and LWFH, we find that job losses concentrate in HPP occupations (as opposed to LPP occupations) across the wage distribution. By contrast, LWFH and HWFH occupations have employment decrease by similar magnitude across the distribution. At the industry level, our results indicate that non-essential industries suffer more serious job losses than essential industries.

We next use our susceptibility results to investigate the underlying mechanism for the large cross-regional variation in employment change. We find that MSAs with larger fractions of workers employed in HPP jobs see steeper declines in total employment. Breaking down employment by sector, the semi-elasticity of Manufacturing employment to the fraction of HPP workers is almost three times that of all-sector or Broad Services employment. Our findings highlight that regional heterogeneity in job composition can lead to large regional variation in employment outcomes in response to the COVID-19 shock.

While our results document heterogeneous employment outcomes at the occupation, industry, and MSA levels in the near-term, some of these short-run impacts may become long-lasting. Structural changes may emerge: Employment may permanently shrink in some sectors, occupations, or regions, but expand in others as the economy exits the pandemic. Recent studies predict that long-term employment effects can come in various forms: reallocation of jobs, workers, and capital across firms and locations in response to pandemic-induced demand shifts (Barrero, Bloom, and Davis (2020)); increased automation of jobs with high infection risk (Chernoff and Warman (2020)), dynamic trade-offs in labor supply (Boar and Mongey (2020)); and long-term unemployment (Chodorow-Reich and Coglianese (2020)), to name a few. With timely data, it would be interesting to explore these as well as other potential structural changes in the labor market as the situation unfolds.

References

Bachas, N., Ganong, P., Noel, P. J., Vavra, J. S., Wong, A., Farrell, D., & Greig, F. E. (2020, July). *Initial impacts of the pandemic on consumer behavior: Evidence from linked income, spending, and savings data* (Working Paper No. 27617). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w27617` doi: 10.3386/w27617

Balla-Elliott, D., Cullen, Z. B., Glaeser, E. L., Luca, M., & Stanton, C. T. (2020, June). *Business reopening decisions and demand forecasts during the COVID-19 pandemic* (Working Paper No. 27362). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w27362` doi: 10.3386/w27362

Barrero, J. M., Bloom, N., & Davis, S. J. (2020, May). *Covid-19 is also a reallocation shock* (Working Paper No. 27137). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w27137` doi: 10.3386/w27137

Bartik, A. W., Bertrand, M., Cullen, Z. B., Glaeser, E. L., Luca, M., & Stanton, C. T. (2020, April). *How are small businesses adjusting to COVID-19? Early evidence from a survey* (Working Paper No. 26989). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w26989` doi: 10.3386/w26989

Bartik, A. W., Bertrand, M., Lin, F., Rothstein, J., & Unrath, M. (2020, July). *Measuring the labor market at the onset of the COVID-19 crisis* (Working Paper No. 27613). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w27613` doi: 10.3386/w27613

Bartik, A. W., Cullen, Z. B., Glaeser, E. L., Luca, M., & Stanton, C. T. (2020, June). *What jobs are being done at home during the Covid-19 crisis? Evidence from firm-level surveys* (Working Paper No. 27422). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w27422` doi: 10.3386/w27422

Bartik, A. W., Cullen, Z. B., Glaeser, E. L., Luca, M., Stanton, C. T., & Sunderam, A. (2020, July). *The targeting and impact of Paycheck Protection Program loans to small businesses* (Working Paper No. 27623). National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w27623` doi: 10.3386/w27623

Boar, C., & Mongey, S. (2020, August). *Dynamic trade-offs and labor supply under the cares act* (Working Paper No. 27727). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27727 doi: 10.3386/w27727

Cajner, T., Crane, L. D., Decker, R. A., Grigsby, J., Hamins-Puertolas, A., Hurst, E., ... Yildirmaz, A. (2020, May). *The U.S. labor market during the beginning of the pandemic recession* (Working Paper No. 27159). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27159 doi: 10.3386/w27159

Campello, M., Kankanhalli, G., & Muthukrishnan, P. (2020, May). *Corporate hiring under COVID-19: Labor market concentration, downskilling, and income inequality* (Working Paper No. 27208). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27208 doi: 10.3386/w27208

Casado, M. G., Glennon, B., Lane, J., McQuown, D., Rich, D., & Weinberg, B. A. (2020, August). *The effect of fiscal stimulus: Evidence from COVID-19* (Working Paper No. 27576). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27576 doi: 10.3386/w27576

Centers for Disease Control and Prevention. (2020, February). *Coronavirus Disease 2019 (COVID-19)*. Retrieved 2020-08-27, from https://www.cdc.gov/coronavirus/2019-ncov/faq.html

Chernoff, A. W., & Warman, C. (2020, July). *COVID-19 and implications for automation* (Working Paper No. 27249). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27249 doi: 10.3386/w27249

Chodorow-Reich, G., & Coglianese, J. (2020, July). *Projecting unemployment durations: A factor-flows simulation approach with application to the COVID-19 recession* (Working Paper No. 27566). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27566 doi: 10.3386/w27566

Coibion, O., Gorodnichenko, Y., & Weber, M. (2020a, May). *The cost of the Covid-19 crisis: Lockdowns, macroeconomic expectations, and consumer spending* (Working Paper No. 27141). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27141 doi: 10.3386/w27141

Coibion, O., Gorodnichenko, Y., & Weber, M. (2020b, April). *Labor markets during the COVID-19 crisis: A preliminary view* (Working Paper No. 27017). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27017 doi: 10.3386/w27017

Cowan, B. W. (2020, June). *Short-run effects of COVID-19 on U.S. worker transitions* (Working Paper

No. 27315). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27315 doi: 10.3386/w27315

Desmet, K., & Wacziarg, R. (2020, June). *Understanding spatial variation in COVID-19 across the United States* (Working Paper No. 27329). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27329 doi: 10.3386/w27329

Dingel, J. I., & Neiman, B. (2020, April). *How many jobs can be done at home?* (Working Paper No. 26948). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w26948 doi: 10.3386/w26948

Fairlie, R. W. (2020a, July). *The impact of COVID-19 on small business owners: Continued losses and the partial rebound in May 2020* (Working Paper No. 27462). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27462 doi: 10.3386/w27462

Fairlie, R. W. (2020b, June). *The impact of Covid-19 on small business owners: Evidence of early-stage losses from the April 2020 Current Population Survey* (Working Paper No. 27309). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27309 doi: 10.3386/w27309

Gupta, S., Montenovo, L., Nguyen, T. D., Rojas, F. L., Schmutte, I. M., Simon, K. I., ... Wing, C. (2020, May). *Effects of social distancing policy on labor market outcomes* (Working Paper No. 27280). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27280 doi: 10.3386/w27280

Kahn, L. B., Lange, F., & Wiczer, D. G. (2020, April). *Labor demand in the time of COVID-19: Evidence from vacancy postings and UI claims* (Working Paper No. 27061). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27061 doi: 10.3386/w27061

Mongey, S., Pilossoph, L., & Weinberg, A. (2020, May). *Which workers bear the burden of social distancing policies?* (Working Paper No. 27085). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27085 doi: 10.3386/w27085

Montenovo, L., Jiang, X., Rojas, F. L., Schmutte, I. M., Simon, K. I., Weinberg, B. A., & Wing, C. (2020, May). *Determinants of disparities in Covid-19 job losses* (Working Paper No. 27132). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27132 doi: 10.3386/w27132

Neilson, C., Humphries, J. E., & Ulyssea, G. (2020, July). *Information frictions and access to the Pay-*

check Protection Program (Working Paper No. 27624). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27624 doi: 10.3386/w27624

Papanikolaou, D., & Schmidt, L. D. (2020, June). *Working remotely and the supply-side impact of Covid-19* (Working Paper No. 27330). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27330 doi: 10.3386/w27330

Rojas, F. L., Jiang, X., Montenovo, L., Simon, K. I., Weinberg, B. A., & Wing, C. (2020, May). *Is the cure worse than the problem itself? Immediate labor market effects of COVID-19 case rates and school closures in the U.S.* (Working Paper No. 27127). National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w27127 doi: 10.3386/w27127

US Department of Homeland Security. (2020). *Guidance on the Essential Critical Infrastructure Workforce: Ensuring Community and National Resilience in COVID-19 Response.* Retrieved from https://www.cisa.gov/publication/guidance-essential-critical-infrastructure-workforce

Appendices

A Tables

Table A1 Occupation-level descriptive statistics

	Mean	SD	Min	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	Max
Panel A. Employment changes									
$\Delta\,\text{Log}(\text{Employment})_{03-04/20}$	−0.18	0.37	−1.16	−0.67	−0.33	−0.12	0.01	0.19	0.69
$\Delta\,\text{Log}(\text{Employment})_{04-06/20}$	0.09	0.39	−0.73	−0.33	−0.09	0.05	0.20	0.57	1.30
$\Delta\,\text{Log}(\text{Employment})_{03-04/19}$	−0.00	0.22	−0.53	−0.27	−0.09	0.00	0.09	0.25	0.61
$\Delta\,\text{Log}(\text{Employment})_{04-06/19}$	0.01	0.28	−0.70	−0.31	−0.12	−0.01	0.12	0.35	0.78
Panel B. Occupational characteristics									
LWFH index	0.29	0.27	0.00	0.00	0.08	0.25	0.50	0.67	1.00
HPP index	0.54	0.19	0.00	0.32	0.40	0.52	0.67	0.81	1.00
Observations	389								

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. Abbreviations: LWFH: Low work from home, HPP: High physical proximity. The continuous LWFH and HPP indices with values in $[0, 1]$ are due to Mongey et al. (2020).

Table A2 Essential industries

Sector	Industries
Agriculture, Forestry, & Fisheries	Agricultural Production, Crops; Agricultural Production, Livestock; Veterinary Services; Landscape & Horticultural Services; Agricultural Services, N.E.C.; Forestry; Fishing, Hunting, & Trapping
Mining	Metal Mining; Coal Mining; Oil & Gas Extraction; Nonmetallic Mining & Quarrying, except Fuels
Construction	All Construction

continued ...

...continued

Sector	Industries
Manufacturing	Meat Products; Dairy Products; Canned, Frozen, & Preserved Fruits & Vegetables; Grain Mill Products; Bakery Products; Sugar & Confectionery Products; Beverage Industries; Misc. Food Preparations & Kindred Products; Food Industries, N.S.; Tobacco Manufactures; Pulp, Paper, & Paperboard Mills; Miscellaneous Paper & Pulp Products; Paperboard Containers & Boxes; Newspaper Publishing & Printing; Printing, Publishing, & Allied Industries, except Newspapers; Plastics, Synthetics, & Resins; Drugs; Soaps & Cosmetics; Paints, Varnishes, & Related Products; Agricultural Chemicals; Industrial & Miscellaneous Chemicals; Petroleum Refining; Miscellaneous Petroleum & Coal Products; Tires & Inner Tubes; Other Rubber Products, & Plastics Footwear & Belting; Miscellaneous Plastics Products; Leather Tanning & Finishing; Footwear, except Rubber & Plastic; Leather Products, except Footwear; Manufacturing, Non-Durable - Allocated; Logging; Sawmills, Planing Mills, & Millwork; Wood Buildings & Mobile Homes; Miscellaneous Wood Products; Furniture & Fixtures; Glass & Glass Products; Cement, Concrete, Gypsum, & Plaster Products; Structural Clay Products; Pottery & Related Products; Misc. Nonmetallic Mineral & Stone Products; Blast Furnaces, Steelworks, Rolling & Finishing Mills; Iron & Steel Foundries; Primary Aluminum Industries; Other Primary Metal Industries; Cutlery, Handtools, & General Hardware; Fabricated Structural Metal Products; Screw Machine Products; Metal Forgings & Stampings; Ordnance; Miscellaneous Fabricated Metal Products; Metal Industries, N.S.; Engines & Turbines; Farm Machinery & Equipment; Construction & Material Handling Machines; Metalworking Machinery; Office & Accounting Machines; Computers & Related Equipment; Machinery, except Electrical, N.E.C.; Machinery, N.S.; Household Appliances; Radio, TV, & Communication Equipment; Electrical Machinery, Equipment, & Supplies, N.E.C.; Electrical Machinery, Equipment, & Supplies, N.S.; Motor Vehicles & Motor Vehicle Equipment; Aircraft & Parts; Ship & Boat Building & Repairing; Railroad Locomotives & Equipment; Guided Missiles, Space Vehicles, & Parts; Cycles & Miscellaneous Transportation Equipment; Scientific & Controlling Instruments; Medical, Dental, & Optical Instruments & Supplies; Photographic Equipment & Supplies

continued ...

...continued

Sector	Industries
Transportation, Communications, & Other Public Utilities	Railroads; Bus Service & Urban Transit; Taxicab Service; Trucking Service; Warehousing & Storage; U.S. Postal Service; Water Transportation; Air Transportation; Pipe Lines, except Natural Gas; Services Incidental to Transportation; Radio & Television Broadcasting & Cable; Wired Communications; Telegraph & Miscellaneous Communications Services; Electric Light & Power; Gas & Steam Supply Systems; Electric & Gas, & Other Combinations; Water Supply & Irrigation; Sanitary Services; Utilities, N.S.
Wholesale Trade	Motor Vehicles & Equipment; Furniture & Home Furnishings; Lumber & Construction Materials; Professional & Commercial Equipment & Supplies; Metals & Minerals, except Petroleum; Electrical Goods; Hardware, Plumbing & Heating Supplies; Machinery, Equipment, & Supplies; Scrap & Waste Materials; Paper & Paper Products; Drugs, Chemicals, & Allied Products; Groceries & Related Products; Farm-Product Raw Materials; Petroleum Products; Alcoholic Beverages; Farm Supplies
Retail Trade	Lumber & Building Material Retailing; Miscellaneous General Merchandise Stores; Grocery Stores; Dairy Products Stores; Retail Bakeries; Food Stores, N.E.C.; Motor Vehicle Dealers; Auto & Home Supply Stores; Gasoline Service Stations; Miscellaneous Vehicle Dealers; Radio, TV, & Computer Stores; Music Stores; Drug Stores; Liquor Stores; Catalog & Mail Order Houses; Fuel Dealers
Finance, Insurance, & Real Estate	Banking; Savings Institutions, Including Credit Unions; Credit Agencies, N.E.C.; Security, Commodity Brokerage, & Investment Companies; Insurance; Real Estate, Including Real Estate-Insurance Offices
Business & Repair Services	Services to Dwellings & Other Buildings; Personnel Supply Services; Computer & Data Processing Services; Detective & Protective Services; Business Services, N.E.C.; Automotive Rental & Leasing, w/o Drivers; Automobile Parking & Carwashes; Automotive Repair & Related Services; Electrical Repair Shops; Miscellaneous Repair Services

continued ...

...continued

Sector	Industries
Personal Services	Funeral Service & Crematories
Professional & Related Services	Offices & Clinics of Physicians; Offices & Clinics of Dentists; Offices & Clinics of Chiropractors; Offices & Clinics of Optometrists; Offices & Clinics of Health Practitioners, N.E.C.; Hospitals; Nursing & Personal Care Facilities; Health Services, N.E.C.; Child Day Care Services; Family Child Care Homes; Residential Care Facilities, w/o Nursing; Social Services, N.E.C.; Engineering, Architectural, & Surveying Services; Accounting, Auditing, & Bookkeeping Services; Research, Development, & Testing Services; Management & Public Relations Services; Miscellaneous Professional & Related Services
Public Administration	Executive & Legislative Offices; General Government, N.E.C.; Justice, Public Order, & Safety; Public Finance, Taxation, & Monetary Policy; Administration of Human Resources Programs; Administration of Environmental Quality & Housing Programs; Administration of Economic Programs; National Security & International Affairs
Active Duty Military	Army; Air Force; Navy; Marines; Coast Guard; Armed Forces, Branch Not Specified; Military Reserves Or National Guard; Unknown

Note: Based on the 1990 industry classification in the CPS and the US Department of Homeland Security (2020)'s *Advisory Memorandum on Identification of Essential Critical Infrastructure Workers during COVID-19 Response*

Table A3 Industry-level descriptive statistics

	Mean	SD	Min	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	Max
Panel A. Employment changes									
Δ Log(Employment)$_{03-04/20}$	−0.15	0.24	−0.74	−0.53	−0.29	−0.11	−0.00	0.14	0.30
Δ Log(Employment)$_{04-06/20}$	0.05	0.27	−0.63	−0.22	−0.07	0.04	0.19	0.40	0.73
Δ Log(Employment)$_{03-04/19}$	0.00	0.15	−0.37	−0.17	−0.06	0.01	0.06	0.17	0.38
Δ Log(Employment)$_{04-06/19}$	−0.02	0.18	−0.58	−0.24	−0.10	−0.00	0.07	0.20	0.39
Panel B. Essential status									
= 1 if essential	0.76	0.42	0.00	0.00	1.00	1.00	1.00	1.00	1.00
Observations	217								

Note: Based on the 1990 industry classification in the CPS. Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. The dummy for essential status is manually assigned in accordance with the US Department of Homeland Security (2020)'s *Advisory Memorandum on Identification of Essential Critical Infrastructure Workers during COVID-19 Response*.

Table A4 MSA-level descriptive statistics

	Mean	SD	Min	p_{10}	p_{25}	p_{50}	p_{75}	p_{90}	Max
Panel A. Employment changes									
Δ Log(Employment)$_{03-04/20}$	−0.13	0.17	−0.83	−0.35	−0.21	−0.12	−0.04	0.04	0.32
Δ Log(Employment)$_{04-06/20}$	0.06	0.19	−0.52	−0.17	−0.04	0.05	0.15	0.30	0.79
Δ Log(Employment)$_{03-04/19}$	0.01	0.13	−0.39	−0.12	−0.05	0.01	0.06	0.16	0.70
Δ Log(Employment)$_{04-06/19}$	−0.00	0.16	−0.72	−0.17	−0.07	−0.00	0.07	0.15	0.65
Panel B. Industrial and occupational composition in 2019									
% jobs in manufacturing	0.15	0.06	0.02	0.07	0.11	0.14	0.19	0.24	0.38
% jobs in broad services	0.72	0.05	0.54	0.65	0.69	0.73	0.75	0.78	0.86
% jobs in EI	0.72	0.04	0.58	0.68	0.70	0.72	0.74	0.78	0.83
% jobs in LWFH	0.45	0.06	0.28	0.38	0.41	0.45	0.48	0.53	0.63
% jobs in HPP	0.54	0.04	0.42	0.50	0.51	0.54	0.57	0.60	0.69
% jobs in NEI and LWFH	0.17	0.03	0.06	0.13	0.15	0.17	0.19	0.22	0.31
% jobs in EI and LWFH	0.37	0.06	0.21	0.30	0.34	0.38	0.41	0.44	0.54
% jobs in NEI and HPP	0.09	0.03	0.03	0.06	0.08	0.09	0.10	0.12	0.20
% jobs in EI and HPP	0.35	0.05	0.17	0.29	0.32	0.35	0.38	0.40	0.49
Panel C. Controls									
2018 median income ($K)	59.22	12.03	35.26	47.22	51.26	56.91	64.91	75.17	124.70
2019 unemployment rate	3.79	1.02	1.88	2.72	3.09	3.64	4.21	4.94	9.58
2019 population (M)	1.05	2.00	0.09	0.16	0.22	0.41	0.85	2.36	19.22
Observations	235								

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Log changes in employment are winsorized at the top and bottom 2.5% within the relevant period. Abbreviations: LWFH: Low work from home occupations, HPP: High physical proximity occupations, EI: Essential industries, NEI: Non-essential industries.

Table A5 MSA Manufacturing employment changes by HPP and LWFH: Recovery

Δ Log(Manufacturing Employment): 04-2020 to 06-2020	(1)	(2)	(3)	(4)
% High Physical Proximity in 2019	0.011	-0.171		
	(0.795)	(0.876)		
% Low work-from-home in 2019			0.008	0.096
			(0.553)	(0.791)
% Essential-industry employment in 2019		-0.035		-0.043
		(0.748)		(0.743)
% Manufacturing employment in 2019		-0.129		-0.141
		(0.551)		(0.591)
Δ Log(Manufacturing Employment): 04-2019 to 06-2019		0.168**		0.168**
		(0.077)		(0.077)
log(Population) in 2019		0.026		0.028
		(0.025)		(0.026)
log(Median household income) in 2018		-0.219		-0.198
		(0.170)		(0.169)
Unemployment rate in 2019		-0.025		-0.027
		(0.032)		(0.033)
Constant	0.022	0.813	0.024	0.582
	(0.426)	(1.108)	(0.239)	(0.922)
Number of MSAs	221	221	221	221
R^2	0.000	0.038	0.000	0.038

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: ** ($p < 0.05$).

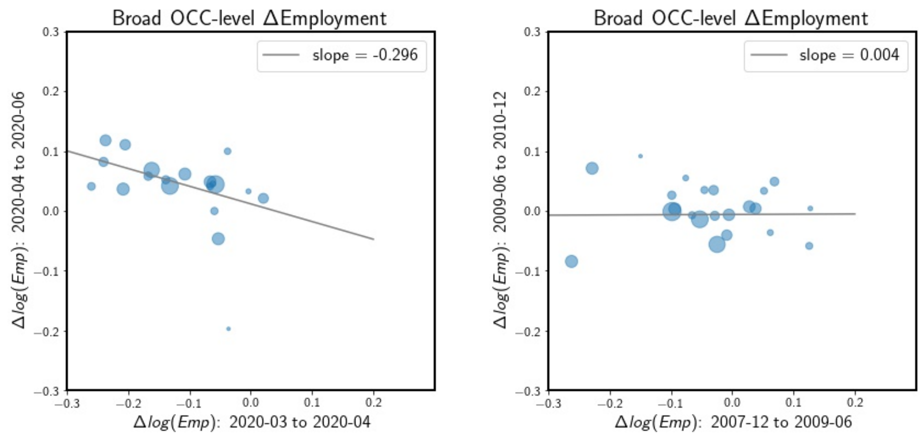
Table A6 MSA-level Broad Services employment changes by HPP and LWFH: Recovery

Δ Log(Broad Services Employment): 04-2020 to 06-2020	(1)	(2)	(3)	(4)
% High Physical Proximity in 2019	-0.289	-0.135		
	(0.470)	(0.577)		
% Low work-from-home in 2019			-0.434	-0.481
			(0.305)	(0.450)
% Essential-industry employment in 2019		1.217*		1.304**
		(0.639)		(0.661)
% Manufacturing employment in 2019		-0.026		-0.073
		(0.731)		(0.716)
% Broad Services employment in 2019		0.815		0.598
		(0.822)		(0.787)
Δ Log(Broad Services Employment): 04-2019 to 06-2019		0.375***		0.375***
		(0.124)		(0.125)
log(Population) in 2019		-0.023		-0.025
		(0.017)		(0.017)
log(Median income) in 2018		0.083		0.042
		(0.128)		(0.126)
Unemployment rate in 2019		-0.007		-0.002
		(0.023)		(0.024)
Constant	0.231	-1.328	0.269**	-0.904
	(0.251)	(1.120)	(0.133)	(1.037)
Number of MSAs	234	234	234	234
R^2	0.002	0.093	0.009	0.099

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Robust standard errors are in parentheses. Significance levels: * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.01$).

B Figures

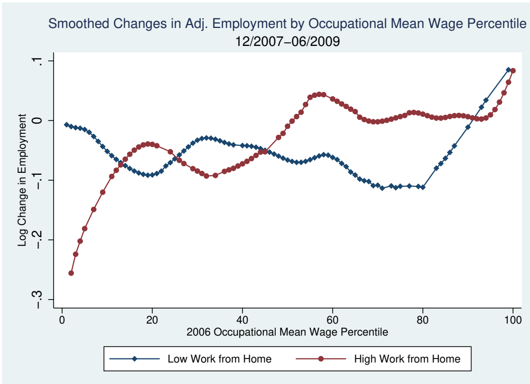
Figure B1 Broad OCC-level Δ Employment: COVID-19 pandemic vs Great Recession



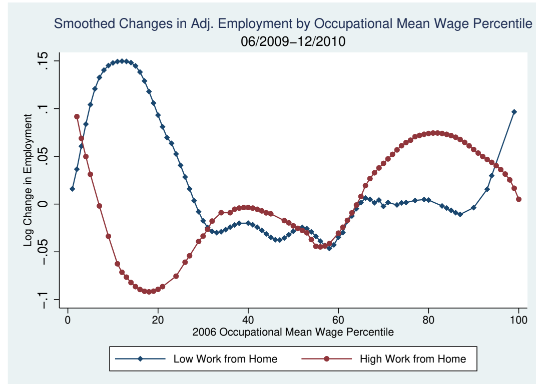
(a) COVID-19 pandemic (b) Great Recession

Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Each panel covers 22 broad occupation categories. The scatter points are weighted by the broad occupation's employment share in March 2020 (panel (a)) and December 2007 (panel (b)).

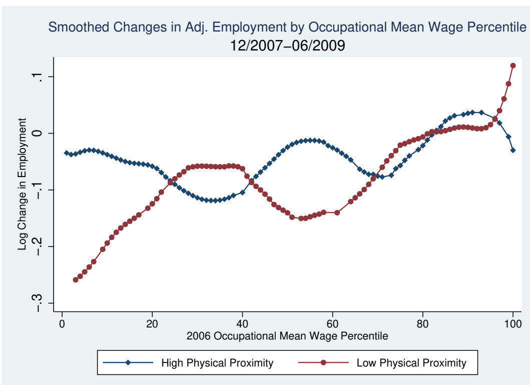
FIGURE B2   Great Recession: Smoothed log changes in adjusted employment by WFH/PP



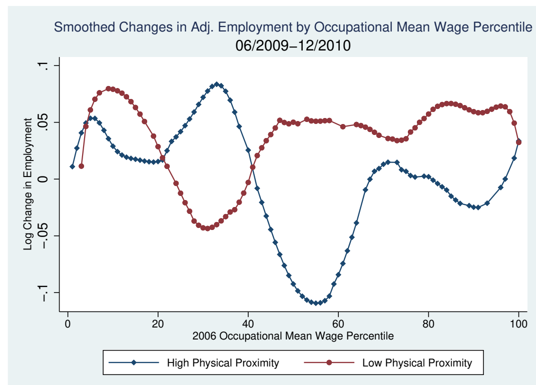
(a) Great Recession: Crisis—WFH



(b) Great Recession: Recovery—WFH



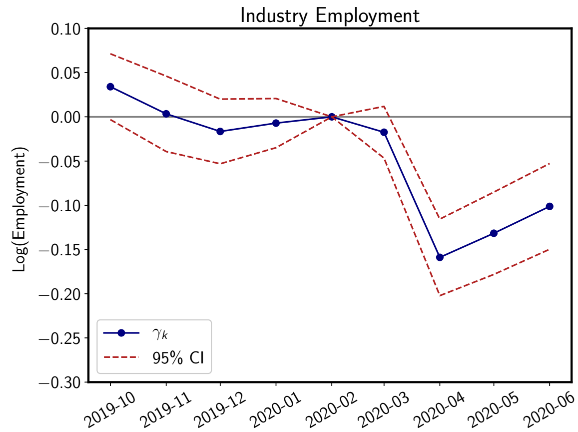
(c) Great Recession Crisis—PP



(d) Great Recession: Recovery—PP

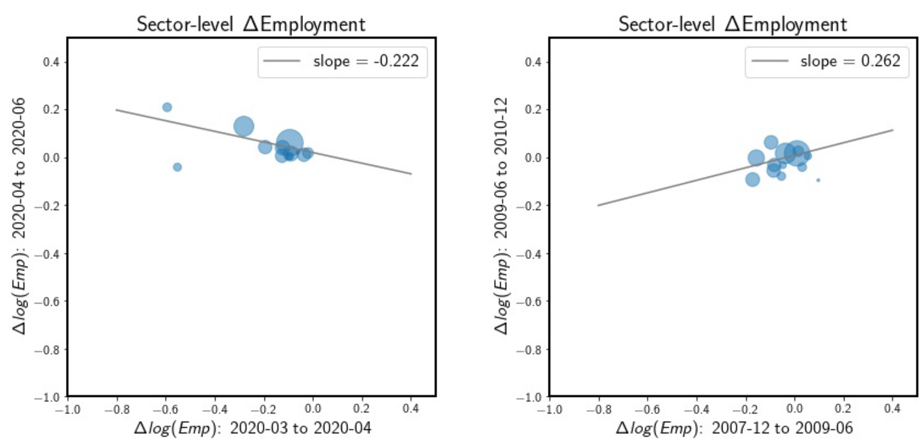
Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Within each period, log changes in employment are winsorized at the top and bottom 2.5% and Lowess-smoothed with a bandwidth of 0.4.

Figure B3 Industrial employment in months surrounding the COVID-19 pandemic



Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Standard errors are clustered at the industry level.

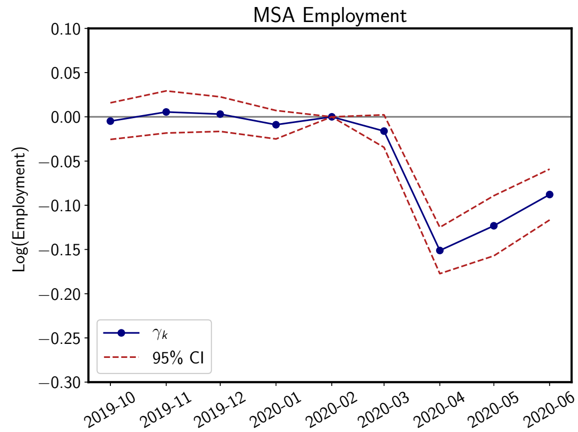
Figure B4 Sector-level Δ Employment: COVID-19 pandemic vs Great Recession



(a) COVID-19 pandemic (b) Great Recession

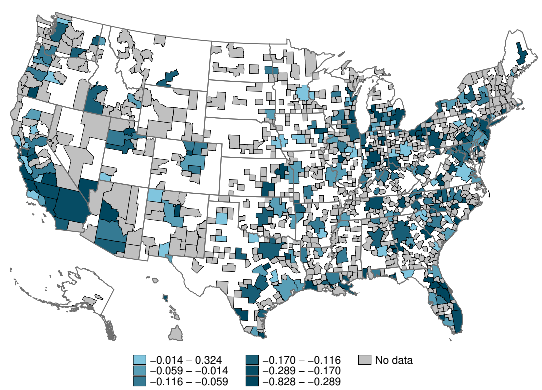
Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Each panel covers 13 sectors. The scatter points are weighted by the sector's employment share in March 2020 (panel (a)) and December 2007 (panel (b)).

Figure B5 MSA employment in months surrounding the COVID-19 pandemic

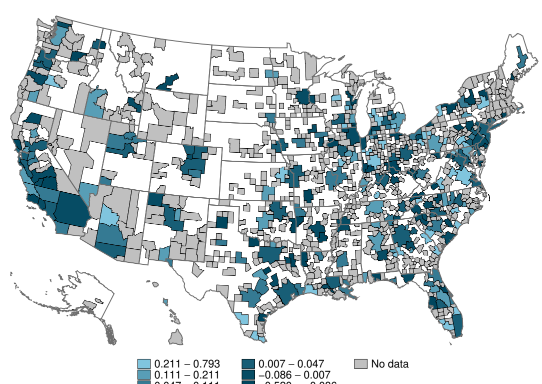


Note: Employment is seasonally adjusted using the X-13ARIMA-SEATS method. Standard errors are clustered at the MSA level.

Figure B6 MSA employment change: Crisis vs Recovery



(a) Crisis phase: March-April 2020



(b) Recovery phase: April-June 2020