Unequal Worker Exposure to Establishment Deaths*

Hugh Macartney, Duke University and NBER

Eric Nielsen, Federal Reserve Board

Viviana Rodriguez, University of Wisconsin – Madison

September 2021

Abstract

It is well understood that adverse economic shocks affect workers nonuniformly. We explore a new channel through which unequal employment outcomes may emerge during a downturn: displacement through the extensive margin of establishment deaths. Intuitively, workers who are concentrated in less resilient establishments prior to an economic decline will be disproportionately affected by its onset. Using rich administrative employment and establishment data for the United States, we show that Black workers bore the brunt of the Great Recession in terms of within-industry employment changes arising from establishment deaths. This finding has important implications for the evolution of worker disparities during future downturns.

JEL Codes: E24, J21, R12, R23

Keywords: Economic Shocks, Worker Inequality, Establishment Deaths, Employment, Firm Resilience, Industry Composition, Gap, Disparity, Decomposition

*We would like to thank Peter Arcidiacono, Patrick Bayer, Sandra Black, Allan Collard-Wexler, participants at the Federal Reserve Bank of Atlanta Micro Labor Workshop, the Triangle Applied Micro Conference and the NBER Conference on Research in Income and Wealth, and anonymous referees for helpful comments and suggestions. Molly Shatto and Sarah Friedman provided excellent research assistance. All remaining errors are our own. The views and opinions expressed in this paper are solely those of the authors and do not reflect those of the Board of Governors or the Federal Reserve System. Contact emails: Macartney, hugh.macartney@duke.edu; Nielsen, Eric.R.Nielsen@frb.gov; Rodriguez, rodriguezand@wisc.edu.

1 Introduction

Against a backdrop of rising inequality, the existence of racial labor market disparities is a key public concern. Economists have studied labor market disparities along several dimensions, focusing on trends in factors including differential worker productivity, the relative supply of workers, unionization, and skill-biased technical change.[1] Considerable attention has also been devoted to understanding the labor market effects of economic shocks, with a view toward worker inequality in several instances.[2] However, existing research has yet to determine whether and how any given shock-inequality connection is mediated by preexisting worker-firm matching, which in particular may vary across racial groups (e.g., white, Hispanic, and Black workers).

The closest that researchers have come to doing so has been through the use of information about displaced workers from survey data. Fairlie and Kletzer (1998) and Wrigley-Field and Seltzer (2020) use the Displaced Worker Survey – a supplement to the Current Population Survey (CPS) – to document how Black and white workers were differentially affected by job displacements during the 1980s and from 1981 to 2017, respectively. However, displacement in these articles includes losses not only from establishment closures, as in our study, but also losses from the elimination of positions/shifts and losses from insufficient demand. These additional sources of displacement potentially conflate pre-downturn matching with post-downturn employer discretion over who to let go during periods of downsizing.

[1] Altonji and Blank (1999) and Katz and Autor (1999) offer excellent reviews of the relevant literature. Seminal early work includes Bound and Freeman (1992), Katz and Murphy (1992), Berman, Bound and Griliches (1994), Autor, Katz and Krueger (1998) and Card and DiNardo (2002), among others. Some notable recent additions to the literature are Autor, Katz and Kearney (2008) and Bayer and Charles (2018).

[2] A large literature examines how employment and earnings respond to changes in trade, government spending and defense spending (see Blau, Kahn and Waldfogel 2000; Aizer 2010; Autor, Dorn and Hanson 2013; Nakamura and Steinsson 2014; Bertrand, Kamenica and Pan 2015; Pierce and Schott 2016, 2017; Goldsmith-Pinkham, Sorkin and Swift 2018). Though these analyses place little emphasis on how labor outcomes might differ across worker types, several other works consider the effects of economic shocks through the prism of worker inequality. These include Bound and Holzer (2000), which applies the methodology proposed by Bartik (1991) and developed more fully by Blanchard and Katz (1992) to analyze decadal patterns in inequality, as well as Couch and Fairlie (2010), Hoynes (1999), Hoynes, Miller and Schaller (2012) and Guvenen, Ozkan and Song (2014), which investigate whether recessions have differential effects by worker type.

Similarly, Davis and von Wachter (2011), which combines CPS data with information from the Business Employment Dynamics database and the Job Openings and Labor Turnover Survey to analyze the effect of job destruction on employment by gender and age from 1974 to 2008, defines destruction to include employment losses stemming from both closing and shrinking establishments. Other notable articles that estimate the effects of recessions and rising unemployment rates on employment by worker race include Badgett (1994), Couch, Fairlie and Xu (2018), and Schwandt and Von Wachter (2019), but none of these consider displacement arising from establishment or firm closures.[3]

In this article, we explore how the pre-recession matching between workers and establishments affects inequality across workers by race, in terms of employment losses related to establishment deaths during the Great Recession.[4] If workers are matched to establishments non-randomly by race, then the racial groups concentrated within establishments least able to survive the downturn will experience a disproportionate share of the employment decline.[5] Focusing exclusively on employment changes from establishment deaths (as opposed to changes from non-closing establishments) is key for understanding the connection between worker inequality and pre-downturn matching, given that, by definition, death-based changes cannot be affected by post-downturn employer favoritism toward one racial group over another. We use the Great Recession, a downturn that was abrupt, deep, and widespread, to uncover evidence of such sorting across establishments by race. Under our approach, the degree to which workers of different races are differentially distributed according to unobservable establishment resilience is revealed by the change in racial employment inequality explained by establishment deaths.

[3]There is also a growing literature that studies the contribution of worker-firm matching to increasing earnings inequality over time (see Abowd, Kramarz and Margolis 1999; Card, Heining and Kline 2013; Barth et al. 2016; Bonhomme, Lamadon and Manresa 2019; Song et al. 2019), but it does not examine how the relationship (or its employment analogue) is affected by large negative shocks.

[4]As noted in Osotimehin and Pappadà (2016), roughly 95% of firms are single-establishment. Thus, employment dynamics at the establishment level should serve as a reasonable proxy for firm-level dynamics.

[5]Research analyzing the effect of demand shocks on firm/establishment closures includes trade-oriented papers, such as Yeaple (2005) and Egger and Kreickemeier (2009), which are not concerned with inequality per se and do not address differences by race or gender. Syverson (2011) reviews a literature documenting substantial productivity differences across firms within narrowly-defined industries.

This concept of resilience is related to but distinct from establishment productivity. In the sizable literature on the "cleansing" of lower-productivity establishments during economic downturns, Foster, Grim and Haltiwanger (2016) note that the cleansing (productivity reallocating) effect appears to have been weaker during the Great Recession relative to prior downturns.[6] To the extent that firm resilience is related to productivity, this result suggests that our estimates might understate the relative employment effects to be found in a more "typical" recession. However, it is worth noting that Lee and Mukoyama (2015) does not find large productivity differences between manufacturing plants exiting during downturns versus those exiting during normal times.

In addition to establishment productivity, resilience during downturns might also be related to a number of other factors identified in the prior literature. One prominent such factor could be financial constraints, as high-productivity but financially vulnerable firms are forced to exit the market during economic recessions (see Osotimehin and Pappadà 2016; Holtz-Eakin, Joulfaian and Rosen 1994; Musso and Schiavo 2008). Similarly, research has generally found greater cyclical employment sensitivity for smaller and younger firms (e.g., Fort et al. 2013; Crouzet and Mehrotra 2020), although these analyses tend not to focus on employment losses stemming specifically from establishment deaths. One exception is Lee and Mukoyama (2015), which finds little difference in the size of manufacturing plants (in terms of employment) exiting at different points in the business cycle.

Another potential correlate of resilience is the race of the business owner, as the Great Recession appears to have impacted Black-owned businesses more severely than white-owned businesses in terms of both employment and survival (Jarmin, Krizan and Luque 2014). To the extent that Black-led businesses have a higher share of Black employment, this channel could account for some of our aggregate findings. The subprime crisis hit Black households particularly hard (Rugh and Massey 2010; Gerardi and Willen 2009), suggesting highly local credit channels as a possible mechanism. Determining how much, if at all, these various factors contributed to resilience during the Great Recession is beyond the scope of our

[6]The literature on productivity reallocation over the business cycle is vast, dating back to at least Schumpeter et al. (1939).

analysis.

The key methodological contribution of this article is to recover the component of the change in employment inequality that is explained by establishment deaths. In our context, this change is defined as the difference across worker race (e.g., white vs. Black) in the aggregate percent change in employment over the Great Recession.[7] As direct and nationally comprehensive measures of worker-specific employment changes arising from establishment deaths are unavailable, we propose a method for statistically decomposing employment changes by worker race into four mutually exclusive and exhaustive components: those due to establishment deaths, births, contractions, and expansions. The approach exploits variation in each of these establishment-level causes while imposing restrictions so that the overall predicted employment changes by race and by cause match those observed in the data.[8]

With the decomposition in hand, we adapt the well-established procedure from the literature for isolating across- and within-industry variation,[9] separating the overall employment change attributed to establishment deaths into across and within components. These terms intuitively depend on the race-specific employment changes and employment shares at the industry level; the across component is a function of the average employment changes across race groups and the differences in shares by race, while the within component is a function of the differences in employment changes by race and the average employment shares across race groups. While the extent to which establishment deaths can explain across-industry patterns is interesting, focusing on the within-industry changes is particularly informative. Doing so rules out the deaths effects from being driven by a correlation between industry-specific preferences and industry vulnerability to demand shocks.

[7]This measure differs somewhat from the metric commonly used in the literature: the change in a particular worker type's share of aggregate employment or earnings. Our variant is particularly conducive to analyzing demand shocks, as it reveals how each race is separately affected. In the case of the standard metric, it is not apparent whether an increase in the share of total employment for a particular race is due to growth for that race or to a contraction in total employment.

[8]While our decomposition method accounts for all categories of establishment-level cause, our establishment death results are given particular prominence, since the death component is the only one for which the employer cannot exercise discretion in firing.

[9]See Freeman (1975), Freeman (1980), Katz and Murphy (1992), Berman, Bound and Griliches (1994), Autor, Katz and Krueger (1998), Dunne, Haltiwanger and Troske (1996), and Bernard and Jensen (1997).

We apply our empirical framework to employment data from the Census Quarterly Workforce Indicators (QWI), broken down by worker race, geography (county), and industry (at the NAICS four-digit level). These publicly available data cover the vast majority of private sector employment for virtually all counties in the United States for the years surrounding the Great Recession. Our near-universal coverage is important – in order to identify the aggregate effect on worker inequality, it is necessary to trace out how *every* industry and *every* county is impacted by the Great Recession, rather than a subset. Our administrative data is in contrast to individual survey data (e.g., CPS), which does not contain a sufficient number of observations to conduct analyses at the four-digit industry by county level, and which may suffer from recall bias. We supplement the QWI with Statistics of U.S. Businesses (SUSB) data from the Census on the number of establishment deaths, births, contractions, and expansions by county and four-digit NAICS. We then link this establishment information to employment shifts by industry, county, and worker race.

Applying our decomposition method reveals substantial changes in employment inequality by race over the Great Recession. In keeping with prior analyses, while all racial groups lost employment, Black workers were disproportionately affected by the downturn, with a decline that was about 25% larger than the loss for white workers and approximately five-sixths larger than Hispanic workers. Black workers fared even worse with respect to employment losses stemming from establishment deaths, losing at twice the rate of white and Hispanic workers.[10]

The decomposition into across- and within-industry components reveals that the more pronounced employment losses for Black workers were driven entirely by within-industry declines, with white and Hispanic workers incurring greater losses as a result of their unfavorable preexisting distribution across industries. More importantly, the within-deaths estimates indicate that Black workers were disadvantaged within industry precisely because they were concentrated in less resilient establishments prior to the recession.

[10]Importantly, local establishment deaths are only modestly correlated with local employment declines – there is meaningful variation in employment that is orthogonal to deaths. Our finding that deaths can explain a substantial fraction of the change in inequality between various worker types is not tautological.

Our work relates to a prior literature that examines the effects of individual establishment closures, arguing that these can be seen as natural experiments that allow researchers to evaluate the wage losses that result from job separations.[11] Our approach offers a complementary view, focusing on aggregate employment losses across all establishment deaths, rather than the subsequent effects of a single establishment death on its former workers. Our finding that minority workers are more likely to be employed at firms that are less resilient to negative shocks and more likely to close is not something one could discern using data from a single establishment.

The remainder of the paper is organized as follows: The next section describes the data used in our analysis. Section 3 sets out our framework for exploring changes in inequality, detailing the procedure for determining the extent to which the gap in the employment growth rates by race can be attributed to each establishment-level cause (deaths, births, contractions, and expansions), as well as decomposing each gap into across- and within-industry components. Section 4 provides several stylized facts about the Great Recession, lending context to our main empirical results, which we present in Section 5. Section 6 then justifies our approach by formalizing the sources and direction of potential bias, undertaking a sensitivity analysis, assessing goodness-of-fit using an out-of-sample exercise, and showing that our results are robust to the use of alternative geographical and industry definitions. Section 7 concludes.

2 Employment and Establishment Death Measures

Our measure of employment comes from the Quarterly Workforce Indicators (QWI; U.S. Census Bureau 2019*a*), which is produced by the U.S. Census Bureau. The QWI provides local labor market employment information by quarter-year, county, industry (four-digit NAICS), and worker demographics (race, ethnicity and gender). These publicly available data are aggregated from the matched employer-employee micro-level Longitudinal Employer-Household

[11] See Couch and Placzek (2010) for a thorough review of this literature.

Dynamics (LEHD) dataset, which is constructed using administrative records from state unemployment insurance fillings, social security data, federal tax records and other Census data. For our period of interest (2007-2009), the QWI data cover 95% of US private sector jobs and all but one state.[12]

Employment totals for certain interactions of worker demographic categories are released publicly. These interactions include race by ethnicity but importantly do not include race by education. Moreover, employment data simultaneously broken down by race, establishment size, and geography is also not available. We draw from race by ethnicity QWI files to define each race group. The categories "white" and "Black" consist of white non-Hispanic and Black non-Hispanic workers, respectively, while "Hispanic" consists of Hispanic workers of any race. Using these definitions, we calculate the employment change during the recession for each race in every county of the U.S. While our employment measures do not condition on full- or part-time status, we draw upon the American Community Survey (ACS; Ruggles et al. 2019) to provide supplemental evidence that changes in the share of part-time workers do not drive our results (see Appendix B.1).

The first column of Panels A and B in Table 1 reports descriptive statistics for the QWI data. The sample contains 3,128 counties and 312 four-digit industries. It covers 122 million jobs, with total employment reported separately by race, industry and county.

To complement our measure of employment, we draw from two different dynamic annual datasets from the Statistics of U.S. Businesses (SUSB; U.S. Census Bureau 2019*b*). The first provides information about the number of establishment deaths, births, contractions, and expansions for each county and four-digit NAICS industry code. The second reports national industry-level changes in employment due to establishment deaths, births, contractions, and expansions.[13] These data are constructed from the Business Information Tracking Series

[12]The QWI data did not report information for Massachusetts until 2010. Only 31 states participate in the LEHD program and, with the exception of a very small subset (8 as of this writing), restricted LEHD data must be obtained on a state-by-state basis (with most researchers obtaining only between 14 and 17 states).

[13]SUSB data are extracted from the Census Business Register which collects data on all known single and multi-establishment firms. These data come from several sources including the Economic Census, the Annual Survey of Manufacturers, the Current Business Surveys, and the administrative records of the Internal

Table 1: Descriptive Statistics

	QWI Sample	SUSB Subsample
Panel A: Industry-County Counts		
Industries	312	289
Counties	3128	3115
Industry-Counties	454,542	395,680
Panel B: Employment		
Total	122,068,351	113,480,392
White	82,291,944	77,058,720
Black	14,466,006	13,171,431
Hispanic	15,859,996	14,389,629
Average by Industry	391,245	392,666
	(792,667)	(788,487)
Average by Jurisdiction	39,024	36,430
	(149,751)	(141,356)
Panel C: Establishment Counts		
Initial Total		6,555,543
Deaths		1,495,878
Births		1,287,049
Contractions		3,813,287
Expansions		3,153,324

Notes: The QWI sample contains labor market outcomes for the universe of industries and counties across all states (except for MA) and the time period 2007-2009. The merged QWI-SUSB data used for the analysis is a subsample of the QWI sample, since the SUSB establishment data contain a slightly smaller subset of industries and counties. The SUSB initial establishment count pertains to 2007, while the changes (deaths, births, contractions and expansions) are from 2007 to 2009. Panels A and B present descriptive statistics for 2007.

(BITS), which longitudinally tracks each establishment in the United States across successive Business Register records.[14] Establishment deaths (births) are defined in the SUSB data as the number of establishments that have positive (zero) employment in the first quarter of the initial year and zero (positive) employment in the first quarter of the subsequent year. Establishment contractions (expansions) are defined as the number of establishments that have larger (smaller) employment in the first quarter of the initial year than in the first

Revenue Service, the Social Security Administration, and the Bureau of Labor Statistics.

[14]Establishments that have undergone no ownership or organizational changes are matched across years according to their Census identifier. BITS is also able to match those that do change using Employer Identification Numbers, business names and addresses, and industry codes. Doing so guards against over-counting deaths or births.

quarter of the subsequent year.

For our primary analysis, we merge the QWI data for 2007-08 and 2008-09 with SUSB establishment data for the corresponding years, forming the "SUSB Subsample" detailed in the second column of Table 1. Comparing the two columns, the subsample used for the analysis includes over 99.6% of counties and 92.6% of industries in the QWI data, accounting for 93% of total employment in the United States. The employment shares of each race – Black, white, and Hispanic – are similar across samples. Panel C of Table 1 reveals that there are about 6.5 million establishments in our sample, with a higher rate of establishment deaths (contractions) than births (expansions) during our period of interest, a deep recession.

As one might expect during a period of low aggregate demand, employment changes and establishment deaths are correlated at the county level. However, the correlation is relatively small (-0.26), indicating that there are substantial employment changes at the county level that are orthogonal to establishment deaths. Births, contractions, and expansions are also correlated somewhat with county-level employment changes, with correlations of 0.07, -0.27, and 0.45, respectively.

3 Empirical Framework

This section details our empirical framework, introducing relevant notation when needed. We first describe our novel statistical procedure for allocating employment losses to establishment categories (deaths, births, expansions, and contractions). We then set out our framework for decomposing changes in employment gaps over time into components that arise from across- and within-industry variation. Finally, we discuss how we conduct inference in our setting via the bootstrap.

3.1 Decomposition of Employment Changes by Establishment-Level Cause

We begin with the key methodological contribution of the paper: a method for using jurisdiction-industry-level variation in establishment deaths, births, contractions, and expansions to generate predicted employment changes due to each of these causes separately by race.[15] We seek to understand how differences in establishment death-induced employment loss by race contributed to changes in employment inequality during the Great Recession. However, note that QWI data only provides aggregate county-industry-race-level employment changes which cannot be attributed to establishment closures alone. Thus, we develop a method that allows us to predict employment changes due to establishment deaths using aggregate QWI employment data. Our headline estimates are then constructed by feeding the predicted changes due to establishment deaths into the across-within industry decomposition developed in the subsection that follows.

Let ΔE_{ij}^{τ} denote the change in the total employment of workers of race τ in industry i and county j between periods $t = 0$ and $t = 1$ (corresponding to 2007 and 2009, respectively, in our context). Similarly, denote by θ_{ij}^{τ} the percent change in employment, and let θ^{τ} denote its aggregated counterpart (across i and j). The goal is to estimate the component of ΔE_{ij}^{τ} attributable to establishment deaths.

Our approach depends on race-agnostic establishment category counts predicting respective race-specific employment changes to a first-order approximation – we justify this assumption in Section 6. Defining d_{ij}, b_{ij}, c_{ij}, and ex_{ij} to be the number of establishment deaths, births, contractions, and expansions, respectively, we recover the predicted changes in employment by estimating the following equation for each race and industry:

$$\Delta E_{ij}^{\tau} = \beta_{d,i}^{\tau} d_{ij} + \beta_{b,i}^{\tau} b_{ij} + \beta_{c,i}^{\tau} c_{ij} + \beta_{ex,i}^{\tau} ex_{ij} + \epsilon_{ij}^{\tau} \,. \tag{1}$$

[15] A jurisdiction is a county in our application of the framework, but it can refer to any geographical definition, in principle.

Notably, our prediction equation omits an intercept, reflecting the fact that deaths, births, expansions, and contractions are the only channels through which employment can change.

We could simply estimate equation (1) using OLS, weighting by industry-county employment in period 0. However, our goal is to construct the best estimates we can for employment changes corresponding to each type of establishment change. To that end, we leverage additional information to constrain our estimation of equation (1) and improve the quality of our predictions, ensuring that our parameter estimates produce predicted employment changes that match various aggregates observed in the data. In particular, we make use of the fact that, at the industry level, we know the total change in employment due to each type of establishment change, as well as the total change in employment (irrespective of cause) for each race. For example, consider employment changes in industry i due to establishment deaths. Given estimates $\hat{\beta}^{\tau}_{d,i}$ for $\tau = \{w, b, h, o\}$ (white, Black, Hispanic, other), our predicted industry-level employment changes due to deaths for each race is given by $\widehat{\Delta E^{\tau}_i}|_d = \hat{\beta}^{\tau}_{d,i} \sum_j d_{ij}$. While we do not observe the analogues of these changes in our data (which is the reason for carrying out this estimation procedure in the first place), we do observe the total industry-level change in employment due to establishment deaths, $\Delta E_i|d$. Therefore, it is natural to make the following restriction involving $\hat{\beta}^{\tau}_{d,i}$ and $\hat{\beta}^{\tau'}_{d,i}$:

$$\Delta E_i|_d = \widehat{\Delta E^{w}_i}|_d + \widehat{\Delta E^{b}_i}|_d + \widehat{\Delta E^{h}_i}|_d + \widehat{\Delta E^{o}_i}|_d \quad \Longrightarrow \quad \frac{\Delta E_i|_d}{\sum_j d_{ij}} = \hat{\beta}^{w}_{d,i} + \hat{\beta}^{b}_{d,i} + \hat{\beta}^{h}_{d,i} + \hat{\beta}^{o}_{d,i}\,. \quad (2)$$

The restriction in equation (2) ensures that the total predicted loss across all racial groups due to an establishment death equals the average employment loss per establishment death observed in the data. Analogous restrictions apply for births, contractions, and expansions.

Similarly, any set of estimates for the parameters in equation (1) yield predicted overall changes in employment separately for τ and τ' workers which can be constrained to equal the observed total employment losses by race:

$$\begin{aligned}\Delta E_i^\tau &= \widehat{\Delta E_i^\tau}|_d + \widehat{\Delta E_i^\tau}|_b + \widehat{\Delta E_i^\tau}|_c + \widehat{\Delta E_i^\tau}|_{ex} \\ &= \hat{\beta}_{d,i}^\tau \sum_j d_{ij} + \hat{\beta}_{b,i}^\tau \sum_j b_{ij} + \hat{\beta}_{c,i}^\tau \sum_j c_{ij} + \hat{\beta}_{ex,i}^\tau \sum_j ex_{ij} \,. \end{aligned} \tag{3}$$

In total, we can impose up to six restrictions (four restrictions as per equation (2) and two restrictions as per equation (3)). However, we have found that the optimization performs better (and is more stable across bootstraps) when the number of constraints is reduced by one. Therefore, our estimation does not impose equation (2) for expansions, as the expansion predictions are not of direct interest to us. Nevertheless, our estimated parameters yield implied aggregate employment changes by firm expansions that are quite close to the observed values.

It is worth emphasizing that because we cannot directly link employment in the QWI to particular establishments, the possibility remains that some of the employment losses we attribute to establishment deaths are actually attributable to a different cause. Nonetheless, the close correspondence between the predicted employment changes and the observed employment changes, using an out-of-sample goodness-of-fit assessment (see Section 6 for details), coupled with the fact that we simultaneously condition on all establishment variables, provides strong support for our attribution. It is difficult to conceive of a driver of employment changes that is distinct from, but correlated with, deaths and which would not be picked up by variation in births, contractions, or expansions. Furthermore, Section 6 also shows that our results would be directionally unchanged even in the face of significant bias in our estimates for the effects of establishment deaths on race-specific employment.

3.2 Decomposition of Employment Gaps by Industry

We now turn to the task of decomposing the across- and within-industry components of employment changes for different races during the Great Recession. Our measure of the overall change in the employment gap between race-τ and race-τ' workers is given by $[\theta^\tau - \theta^{\tau'}]$. To determine how much of this difference is due to *within-industry* and *across-industry* variation, we define *within-industry* variation as arising from within-industry differences in

race-specific growth rates: that is, $\theta_i^\tau \neq \theta_i^{\tau'}$ for some i. *Across-industry* variation can then be recovered from the difference between overall and within-industry adjustments.

As detailed in Online Appendix D, the within-industry component is given by

$$[\theta^\tau - \theta^{\tau'}]_W = \sum_i (\theta_i^\tau - \theta_i^{\tau'}) \left[\frac{(E_{i0}^\tau / E_0^\tau) + (E_{i0}^{\tau'} / E_0^{\tau'})}{2} \right] . \tag{4}$$

Intuitively, it is the across-industry sum of the difference in the employment losses by race, weighted by the average share of employment in industry i. Similarly, the across-industry component is given by

$$[\theta^\tau - \theta^{\tau'}]_A = \sum_i \left(\frac{\theta_i^\tau + \theta_i^{\tau'}}{2} \right) \left(\frac{E_{i0}^\tau}{E_0^\tau} - \frac{E_{i0}^{\tau'}}{E_0^{\tau'}} \right) . \tag{5}$$

It is the across-industry sum of the difference in industry-i employment shares by race, weighted by the (unweighted) average employment loss in i.

Note that the decomposition $[\theta^\tau - \theta^{\tau'}] = [\theta^\tau - \theta^{\tau'}]_W + [\theta^\tau - \theta^{\tau'}]_A$ can be carried out using either the observed employment changes by race (as in the explication above) or the changes predicted from establishment deaths (or any other establishment cause).

3.3 Interpreting Significance Under the Bootstrap

We construct confidence intervals and p-values for all of our estimates using 5,000 bootstrap iterations, sampling at the county level. To our knowledge, we are the first paper to conduct formal inference on across/within industry decompositions. While the construction and interpretation of the bootstrapped confidence intervals is straightforward, interpreting the p-values is more complicated. The problem is two-fold.

First, we do not know the sampling distribution of our statistics under the relevant null hypotheses, in part because many of these nulls are very likely not true. We address this difficulty by following the recommended approach of shifting the bootstrapped distributions so that they are centered around their respective nulls.

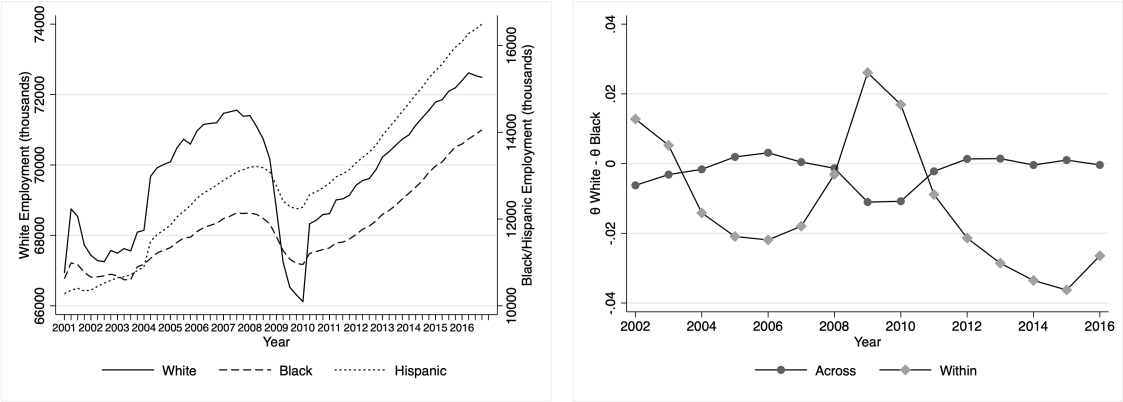
Second, shifting the bootstrapped distributions in this way assumes that they differ only in their locations under different null and alternative hypotheses. We are unaware of any

a priori reason why this should be true, and the constraints we impose in our estimation (equations (2) and (3)) render simultaneous, independent shifts of constraint-linked bootstrapped distributions problematic. Therefore, while we report both p-values and confidence intervals for the results presented in Section 5, we view the confidence intervals as more reliable measures of the sampling variability of our estimates.

4 Stylized Facts about the Great Recession

Before discussing our main results decomposing employment changes during the Great Recession into across- and within-industry components, as well as components stemming from establishment deaths, we present a number of motivating facts about the period of interest.

The Great Recession substantially impacted establishment deaths and births. The SUSB data reveal that establishment deaths began to increase in 2006, peaking in 2008 and 2009 during the height of the recession. Births, by contrast, rose in 2006 and 2007 before falling substantially during the recession. These establishment changes generated intuitive and significant employment changes, with the employment losses from deaths rising and the gains from births falling during the Great Recession, relative to their prior trends (see Online Appendix Figure B.5).



(a) Aggregate by Race

(b) Across/Within, White vs. Black

Figure 1: Aggregate Employment Trends and Decomposition by Worker Race

Notes: Panel (a) of this figure shows the quarterly evolution of seasonally adjusted employment by race (white, Black, and Hispanic) from 2001 to 2016 inclusive. Panel (b) shows the evolution of the across and within components of the observed difference in the percent change in employment between Black and white workers from 2001 to 2016 inclusive. We seasonally adjust employment trends using seasonal adjustment software by the US Census Bureau, entitled "X-13-ARIMA-SEATS." Employment trends for the full population of workers (irrespective of race) are presented in Online Appendix Figure B.4.

Panel (a) of Figure 1 presents aggregate employment trends using the QWI data for white, Black, and Hispanic workers from 2001Q1 to 2016Q4. These seasonally-adjusted employment trends show that while white workers experienced a sizable decrease in employment, their recovery following the Great Recession was faster than the recovery experienced by Black workers. These trends also show that Hispanic workers fared the best of the three groups, in terms of having both a comparatively shallow decline during the recession and a very robust recovery.

While all worker types and most industries experienced declines during the Great Recession,[16] these losses were not even. Some industries were much more heavily affected than others, and variation in worker composition by industry, implies that the "across" inequality channel is likely to be important in many cases. Moreover, in some industries, the Great Recession differentially affected different races, suggesting that the "within" channel may frequently be salient as well.[17]

We now use the decomposition framework set out in Section 3 to understand how across-

[16]Several industries actually experienced employment *increases* during the Great Recession (e.g., health, management services).

[17]See figures in Online Appendix E.

and within-industry employment inequality evolved between 2001 and 2016. In particular, we want to know whether the Great Recession had a pronounced effect on the across and within components, by assessing the extent to which there was a trend break during that time. Doing so isolates the effect of the demand-side recessionary shock from other long-run changes (e.g., prior trends and lagged effects of earlier shocks), which we assume continue to operate during the downturn. This provides suggestive evidence for the formal analysis that follows in Section 5.

Panel (b) of Figure 1 plots the year-over-year across and within components for the comparison between white and Black workers. Changes in the across component generally contribute relatively little to the larger overall employment decline for Black workers during the recession. Rather, this larger relative decline is mainly driven by the within component, which spiked from negative to positive during the recession. Black workers experienced much greater employment losses than white workers within industries during the downturn and had much greater employment growth at the industry level during the recovery. Interestingly, the across component does dip down slightly during the recession – the differential distribution of white and Black workers across industries and the differential employment declines experienced by different industries on net partially counteracted the within-industry forces. For periods outside of the recession, the within component is mostly negative, consistent with faster employment growth experienced by Black workers during the non-recession years. The patterns are similar for the white-Hispanic comparison (available upon request).

5 Main Results

In this section, we present our headline decomposition results. The previous section showed that the Great Recession generated substantial changes in employment inequality, with the within-industry component harming Black workers and the across-industry component helping them, relative to white workers. We now report formal estimates of these effects and then assess the degree to which they can be explained by establishment deaths. We carry

out this analysis by implementing the various decompositions set out in Section 3.

We first consider the total employment changes ("Total") by worker race, as well as the corresponding changes predicted from establishment deaths ("Deaths"). Panel A of Table 2 presents these results, which show how different workers fared over the Great Recession without adjusting for the distribution of employment across industries. Black workers lost modestly more total employment during the recession than white workers (7.2% versus 5.8%). Hispanic workers fared somewhat better, with total employment losses (3.9%) that were about two-thirds those of white workers. However, the deaths-based component paints a different picture: white and Hispanic workers lost about the same employment from establishment deaths (8.4% and 8.1%, respectively), but Black employment declined by nearly twice as much in percentage terms (16.5%). The larger employment decline from establishment deaths for Black workers suggests that they were particularly concentrated in less resilient establishments at the onset of the recession.

Having established the overall effects of the Great Recession, we now turn to the role that industries played (and perhaps more importantly, the role they did not play) in explaining these patterns. In particular, workers are not distributed evenly across industries, so that some of the differential employment losses reported in Panel A of Table 2 may be due to industry-level heterogeneity in the severity of the recession rather than differences in how different worker types are matched to firms within industry. The cleanest test of the hypothesis that disadvantaged workers tend to be concentrated in less resilient firms therefore is to compare the within-industry components of the total and predicted-from-deaths employment changes.

The bottom two panels of Table 2 carry out this comparison by reporting the across- and within-industry components for the total employment changes, as well as those predicted from establishment deaths, for white versus Black workers (Panel B) and white versus Hispanic workers (Panel C). All of the within- and across-industry components for total employment are statistically and economically significant, and some of the deaths counterparts are significant as well.

Table 2: Employment Change Decompositions by Race

Panel A: Overall Employment Changes		
	Total	Deaths
θ^w	-0.058***	-0.084***
	[-0.061,-0.055]	[-0.090,-0.075]
	(0.000)	(0.000)
θ^b	-0.072***	-0.165***
	[-0.077,-0.067]	[-0.202,-0.133]
	(0.000)	(0.000)
θ^h	-0.039***	-0.081***
	[-0.047,-0.031]	[-0.120,-0.052]
	(0.000)	(0.001)
Panel B: Across-Within Comparisons (White vs. Black)		
	Total	Deaths
$[\theta^w - \theta^b]_A$	-0.011***	-0.011
	[-0.013,-0.009]	[-0.028,-0.003]
	(0.000)	(0.179)
$[\theta^w - \theta^b]_W$	0.025***	0.091***
	[0.021,0.028]	[0.062,0.139]
	(0.000)	(0.000)
Panel C: Across-Within Comparisons (White vs. Hispanic)		
	Total	Deaths
$[\theta^w - \theta^h]_A$	0.013***	-0.014***
	[0.010,0.016]	[-0.021,-0.006]
	(0.000)	(0.001)
$[\theta^w - \theta^h]_W$	-0.032***	0.010
	[-0.039,-0.027]	[-0.023,0.055]
	(0.000)	(0.579)

Notes: Panel A presents employment changes during the Great Recession (2007-2009) by worker race, both in total (agnostic to the establishment-level cause) and for those arising from establishment deaths. White, black and Hispanic workers are denoted by w, b and h, respectively. Panel B and C presents estimates of equations (4) and (5) for the white-black and white-Hispanic comparison, respectively, both in total and for establishment deaths. 95% confidence intervals and significance are calculated using 5,000 bootstrap iterations. Confidence intervals are reported in square brackets and p-values are reported in parentheses. *** denotes significance at the 1% level.

Focusing on the total employment effects in the first column, it should be clear that the overall patterns presented in Panel A of Table 2 are potentially misleading as to the effects of the Great Recession on employment inequality. To see why, consider the white vs. Black comparison in Panel B. The slightly larger total employment decline for Black workers stems

entirely from a much greater decline within-industry, with the distribution of Black workers across industries actually serving to protect them somewhat from the downturn, relative to white workers. Accounting for that variation, the within-total effect becomes substantially more positive (2.5 versus 1.4 percentage points overall). The opposite story pertains to the white-Hispanic comparison in Panel C: white workers fared better than Hispanic workers across industries, but substantially worse within industries, with total white employment falling by 3.2 percentage points more than the decline for Hispanic workers.

For the white versus Black comparisons, the across and within total employment effects agree with their deaths-based counterparts in sign if not in magnitude. Across industry, the total and deaths-based estimates are identical at -1.1 percentage points, indicating a slight relative advantage for black workers, although the deaths estimate is not statistically significant. Within-industry, both estimates suggest that Black workers lost significantly more employment than white workers. However, the total effect, at 2.5 percentage points, is substantially smaller than the deaths-based effect, at 9.1 percentage points.

In terms of total and death-based effects agreeing in sign, the white-Hispanic comparison contrasts with the white-Black results. Establishment closures reduced employment more for white workers across industries, with a 1.4 percentage point decline in white employment relative to Hispanic employment. However, within industries, Hispanic workers fared slightly worse, with a one percentage point decline in employment relative to white workers (though we cannot statistically reject this effect being zero).

The central takeaway from Table 2 is that Black and Hispanic workers were disproportionately concentrated in less resilient establishments within industries at the onset of the recession, though only the estimate for the white-Black comparison is statistically distinguishable from zero. Whether due to skill differences or discrimination (the determination of which is beyond the scope of this article), the differential within-industry concentrations of workers implied by these results has important consequences for inequality during future downturns.

6 Justifying Our Approach

Recall from Section 3.1 that our approach relies on establishment category (deaths, births, contractions, and expansions) counts correctly predicting race-specific employment changes associated with that category. If they do, then the coefficients in estimating equation (1) should be unbiased. Assessing the extent to which this is the case requires setting out the econometrics of our approach in greater detail. As our primary interest centers on the death-based estimates in Table 2, we focus on that component of the decomposition.

Suppose the true data generating process for the death-based type-specific employment change is $\Delta E^{\tau}_{d,i,j} = -d_{ij} \cdot \bar{E}^{\tau}_{d,i,j}$, where $\bar{E}^{\tau}_{d,i,j}$ depends on the average size of establishments destined to close, and the proportion of race-τ workers in such establishments, at the $i-j$ level. Let $\Delta E^{\tau}_{d,i,j} = \widehat{\Delta E}^{\tau}_{i,j}|_d + \widetilde{\Delta E}^{\tau}_{d,i,j}$, where $\widehat{\Delta E}^{\tau}_{i,j}|_d = \hat{\beta}^{\tau}_{d,i} d_{ij}$, with analogous expressions and decompositions for the other establishment categories. Thus, we can be explicit about the error term in equation (1): $\epsilon^{\tau}_{ij} = \widetilde{\Delta E}^{\tau}_{d,i,j} + \widetilde{\Delta E}^{\tau}_{b,i,j} + \widetilde{\Delta E}^{\tau}_{c,i,j} + \widetilde{\Delta E}^{\tau}_{ex,i,j}$.

Defining $\eta^{\tau}_{\diagdown d,i,j} \equiv \epsilon_{ij} - \widetilde{\Delta E}^{\tau}_{d,i,j}$, $\hat{\beta}^{\tau}_{d,i}$ (and thus $\widehat{\Delta E}^{\tau}_{i,j}|_d$) could be biased if d_{ij} is correlated with the unobserved determinants of births, contractions or expansions; that is, $cov(d_{ij}, \eta^{\tau}_{\diagdown d,i,j}) \neq 0$. Based on Table 2, the problematic case for our analysis would be downward bias for Black workers ($cov(d_{ij}, \eta^{b}_{\diagdown d,i,j}) < 0$) and upward bias for white workers ($cov(d_{ij}, \eta^{w}_{\diagdown d,i,j}) > 0$). This could only occur if the non-death establishments in counties with a higher number of establishment deaths systematically hire (fire) black workers at a lower (higher) rate than their white counterparts, conditional on the number of establishment births, contractions, and expansions. We view this as unlikely, particularly given the strong out-of-sample performance of our method, discussed below. Moreover, if firm deaths really do disproportionately affect black employment, as implied by our estimates, the larger supply of newly-unemployed black workers should push further against relatively low Black hiring in deaths-intensive counties.

However, even if the direction of bias is problematic for our primary conclusion – that within-industry Black workers lost greater employment than white workers from establish-

ment deaths over the Great Recession – the magnitude of the bias would have to be fairly large to explain the effects we find. In particular, relative to the estimated coefficient, the true coefficient for white workers and Black workers would need to be 60 percent larger and smaller, respectively, for the true within-deaths effect associated with Panel B of Table 2 to be zero (see Online Appendix Figure F.1).

Beyond this sensitivity analysis, a feasible way to assess the accuracy of our procedure for statistically allocating employment changes to establishment categories is to carry out a goodness-of-fit exercise. This entails determining how well predicted out-of-sample total employment changes by race, changes in total employment inequality between races, and across/within decompositions of these inequality changes accord with the observed analogues. We do so by randomly splitting the full sample of counties into two equally-sized groups, with the randomization stratified by county employment. We then estimate equation (1) on the first group of sampled counties to recover estimated coefficients for each race ($\hat{\beta}^{\tau}_{d,i}, \hat{\beta}^{\tau}_{b,i}, \hat{\beta}^{\tau}_{c,i}, \hat{\beta}^{\tau}_{ex,i}$). Finally, we predict the employment changes for the other group of counties (the hold-out group) using these estimated parameters. We repeat this procedure 500 times.

Table 3: Out-Of-Sample Fit by Race (White vs. Black)

	(1) Mean Observed θ	(2) Mean Predicted θ	(3) Mean Difference	(4) SD of Difference
θ^w	-0.058	-0.058	-0.000	0.003
θ^b	-0.072	-0.074	0.002	0.008
$\theta^w - \theta^b$	0.014	0.016	-0.002	0.007
$[\theta^w - \theta^b]_A$	-0.011	-0.012	0.001	0.002
$[\theta^w - \theta^b]_W$	0.025	0.028	-0.003	0.008

Notes: This table presents statistics related to the out-of-sample prediction outlined in the main text. All statistics are based on 500 randomly-drawn estimation and holdout samples, stratified on county-level employment. Columns (1) through (3) present averages of estimates obtained for each random draw. Column (4) presents the standard deviation of Column (3).

Table 3 reports the results of this exercise comparing white workers to Black workers. On average, the predicted values of θ^{τ}, $\theta^{\tau'}$, $\theta^{\tau} - \theta^{\tau'}$, $[\theta^{\tau} - \theta^{\tau'}]_A$, and $[\theta^{\tau} - \theta^{\tau'}]_W$ for the hold-out samples are very close to their observed values. Moreover, for all measures, the variance of

the difference between the predicted and observed value is uniformly small, suggesting that our approach rarely makes large errors. Online Appendix Table F.1 repeats the analysis for the white-Hispanic comparison. The predicted values are again very close to the observed values, with relatively modest variances. The consistently accurate out-of-sample predictions of our method lends credence to our main estimates.

Table 4: Robustness to Alternative Geographical and Industry Definitions

	(1) 4-Digit by County	(2) 3-Digit by County	(3) 3-Digit by CZ	(4) 4-digit by CZ
θ^w	-0.084***	-0.076***	-0.086***	-0.084***
	[-0.090,-0.075]	[-0.097,-0.064]	[-0.110,-0.060]	[-0.104,-0.069]
	(0.000)	(0.000)	(0.000)	(0.000)
θ^b	-0.165***	-0.227***	-0.153***	-0.138***
	[-0.202,-0.133]	[-0.296,-0.140]	[-0.244,-0.062]	[-0.199,-0.067]
	(0.000)	(0.000)	(0.002)	(0.000)
$[\theta^w - \theta^b]_A$	-0.011	-0.008	-0.019*	-0.018**
	[-0.028,0.003]	[-0.045,0.017]	[-0.036,0.002]	[-0.036,-0.002]
	(0.179)	(0.649)	(0.052)	(0.041)
$[\theta^w - \theta^b]_W$	0.091***	0.159***	0.086*	0.073*
	[0.062,0.139]	[0.067,0.229]	[-0.011,0.183]	[-0.012,0.140]
	(0.000)	(0.000)	(0.083)	(0.071)

Notes: This table presents estimates for deaths-related employment changes during the Great Recession (2007-2009) for white and black workers (denoted by w and b, respectively), as well as across- and within-industry deaths-based white-black differences (using equations (4) and (5)). Column (1) reproduces the relevant estimates from Table 2, column (2) presents estimates for 3-digit industry employment and county-level geography, column (3) presents estimates for 3-digit industry employment and commuting zone-level geography, and column (4) presents estimates for 4-digit industry employment and commuting zone-level geography. 95% confidence intervals and significance are calculated using 5,000 bootstrap iterations. Confidence intervals are reported in square brackets and p-values are reported in parentheses. *** denotes significance at the 1% level; ** denotes significance at the 5% level; and * denotes significance at the 10% level.

To the extent that displaced workers can quickly regain employment by moving to related industries and nearby locales, the fine level of geography (county) and industry (4-digit NAICS) used in Table 2 might not yield economically relevant measures of employment losses due to establishment deaths. Table 4 addresses this concern, showing similar Black-white within-deaths estimates to Table 2 (estimates reproduced in column (1), for convenience) for less granular geographical and industry definitions. In particular, using 3-digit industry employment and county-level geography (column (2)) yields an even larger point estimate for within-deaths (0.159 versus 0.091), while using either 3- or 4-digit industry definitions

with commuting zones (CZ) rather than counties yields very similar – and statistically indistinguishable – estimates as Table 2 (see columns (3) and (4)).[18]

7 Conclusion

In this paper, we considered the extent to which the evolution of worker inequality by race during an economic downturn is dictated by preexisting worker-firm matching. We did so by developing an approach that makes use of publicly available data, exploiting variation in employment by race and establishment deaths across counties. Focusing on employment changes from establishment deaths (as opposed to changes from non-closing establishments) is key for understanding the connection between racial inequality and pre-downturn matching, given that, by definition, death-based changes cannot be affected by post-downturn employer favoritism toward one race over another. Applying our method to analyze employment losses during the Great Recession, we found that, within industry, Black workers were disproportionately matched with less resilient establishments prior to the downturn, which resulted in larger subsequent employment losses than experienced by their white or Hispanic counterparts. Our paper lays the foundation toward a deeper understanding of the role that economic downturns play in generating inequality.

[18]We use 2010 Economic Research Service Commuting Zone delineations, developed and published by the Penn State Commuting Zones/Labor Markets data repository (see Fowler and Jensen 2020).

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Appendices

A Additional Detail about Merging QWI with SUSB

We merge QWI and SUSB data at the county-industry level from 2007 to 2009. The 2007-08 SUSB dataset uses the 2002 NAICS classification while the 2008-09 dataset uses the 2007 classification. As the QWI uses the 2012 classification, we convert all industry categories to the 2012 definition using equivalences published by the Census, before merging the data sources. While the SUSB data contain six-digit industry codes, we use the more aggregated four-digit measure to match the aggregation level of our QWI employment data.

Additionally, SUSB excludes some NAICS codes, including crop and animal production (NAICS 111,112), rail transportation (NAICS 482), postal service (NAICS 491), pension, health, welfare, and vacation funds (NAICS 525110, 525120, 525190), trusts, estates, and agency accounts (NAICS 525920), private households (NAICS 814), and public administration (NAICS 92).

B Additional Stylized Facts

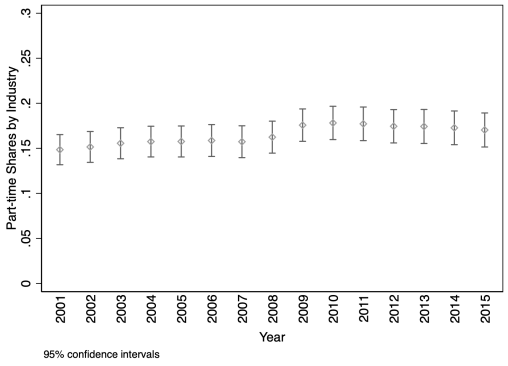
B.1 Part-Time Employment

The QWI data does not distinguish between full-time and part-time employment. This complicates the interpretation of our results because the Great Recession may cause shifts on both the employed/not-employed margin and the full-time/part-time margin. Our method and data will not detect industry responses which shift workers between part-time and full-time roles. Although we cannot address this concern directly, we can nonetheless present evidence that the share of part time work is reasonably stable (1) across industries and (2) within industries over time.

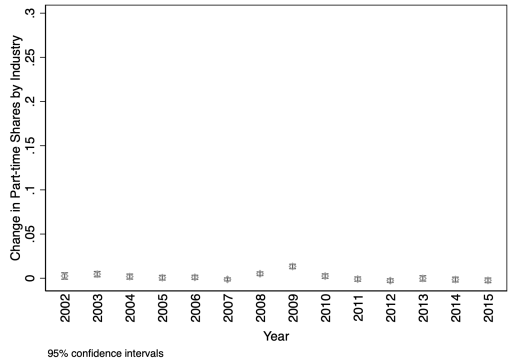
We use the ACS to estimate the share of part-time and full-time workers by four-digit industry code. Panel (a) of Figure B.1 plots the mean and 95% confidence interval for the share of part time workers by industry for each ACS year (2001 to 2015). The means are around 0.15-0.18, which matches aggregate estimates from the BLS quite well.[19] Moreover, the variance in this share across industries is fairly small each year, with the 95% confidence intervals generally spanning only about 0.025 percentage points. The part-time share increased modestly from 0.16 to 0.18 during the recession, suggesting across-industry stability.

With respect to within-industry stability, Panels (b) and (c) of Figure B.1 show that the part-time shares did not change very much within industry over our sample period. In 2008 and 2009, the part time share increased for most industries, while the typical change aside from these two years is around 0. However, even in 2009, the typical industry only saw

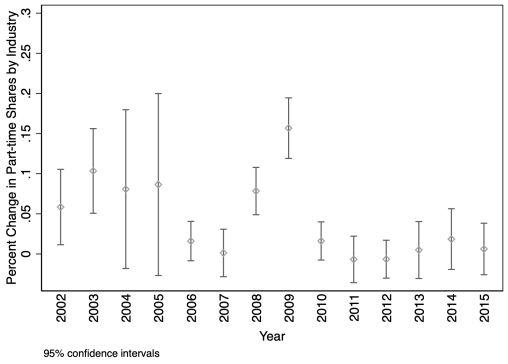
[19] Compare BLS series LNS11000000 (total labor force) to LNS12600000 (part time labor force).



(a) Across-Industry Levels



(b) Within-Industry Changes



(c) Within-Industry Percent Changes

Figure B.1: Part-Time Employment Shares Across and Within Industries (2001-2015)

Notes: This figure shows the evolution of part-time employment shares across industries from 2001 to 2015 inclusive. In particular, panels (a), (b) and (c) show yearly variation in the level, change and percent change in part-time employment, respectively.

its part-time share increase by about 0.015 percentage points (off of a base of about 0.16 percentage points). Taken together, these figures suggest that the distinction between part- and full-time is not an important source of within-industry variation.

B.2 Population Share and Labor Force Participation by Race

To provide additional context for our results, we document trends in the population share and labor force participation by race surrounding the Great Recession. Using supplemental ACS data, Figure B.2 plots the population share for Black and Hispanic people over time. The share of Black and Hispanic people is rising during the 2000s, but the trend does not change during the onset of the recession.

We also use the ACS data to plot the labor force participation by race in Figure B.3. There is a temporary uptick in the participation of all races during the recession, against a generally declining trend. However, given that it is very small relative to the level of labor force participation for each race, we do not expect our results in Section 5 to be driven by such patterns.

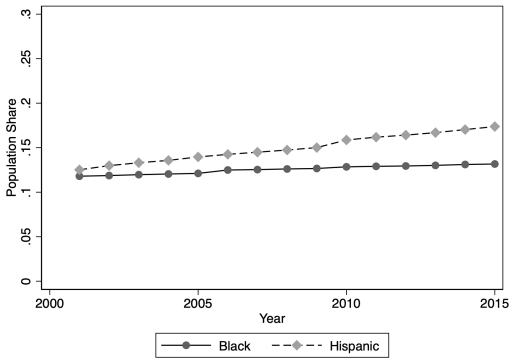


Figure B.2: Population Share by Race (2001-2015)

Notes: This figure shows the evolution of population share by race from 2001 to 2015 inclusive.

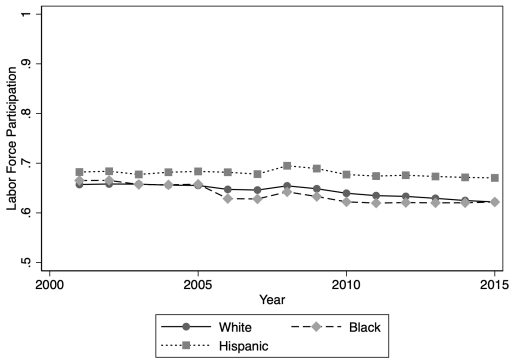


Figure B.3: Labor Force Participation by Race (2001-2015)

Notes: This figure shows the evolution of labor force participation by race from 2001 to 2015 inclusive.

B.3 Aggregate Employment 2001-2016

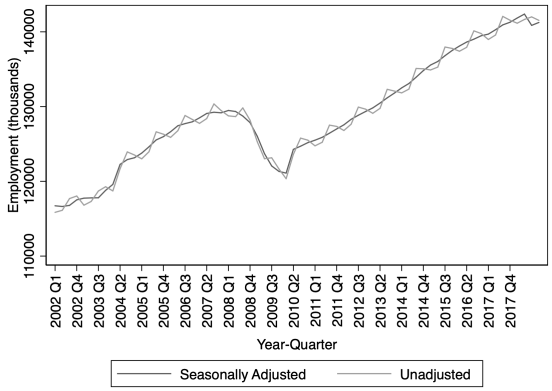
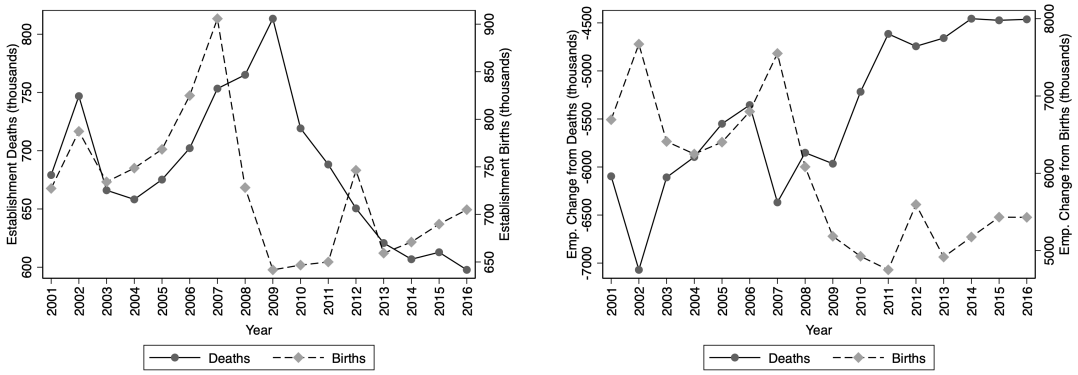


Figure B.4: Aggregate Employment Trends (2001-2016) – QWI Data

Notes: This figure shows the quarterly evolution of aggregate employment from 2001 to 2016 inclusive with and without seasonality adjustments.

B.4 Establishment Deaths and Births in the SUSB



(a) Establishment Deaths and Births (b) Employment Loss due to Deaths and Births

Figure B.5: Trends in Establishment Deaths and Births (2001-2016) – SUSB Data

Notes: Panel (a) shows the evolution of establishment deaths and births from 2001 to 2016, while Panel (b) shows the trend in employment loss (gain) due to deaths (births) over time.

C Spatial Variation

Figure C.1: Percent Employment Change 2007-2009 by County

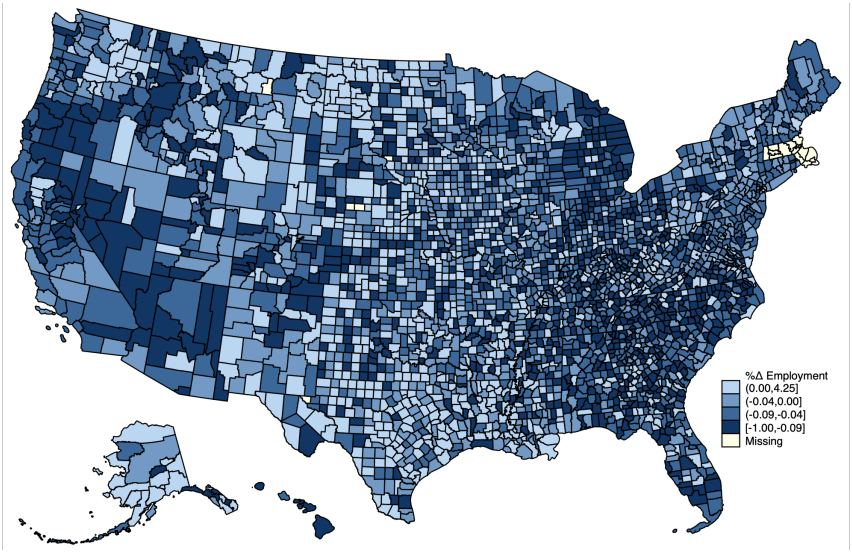
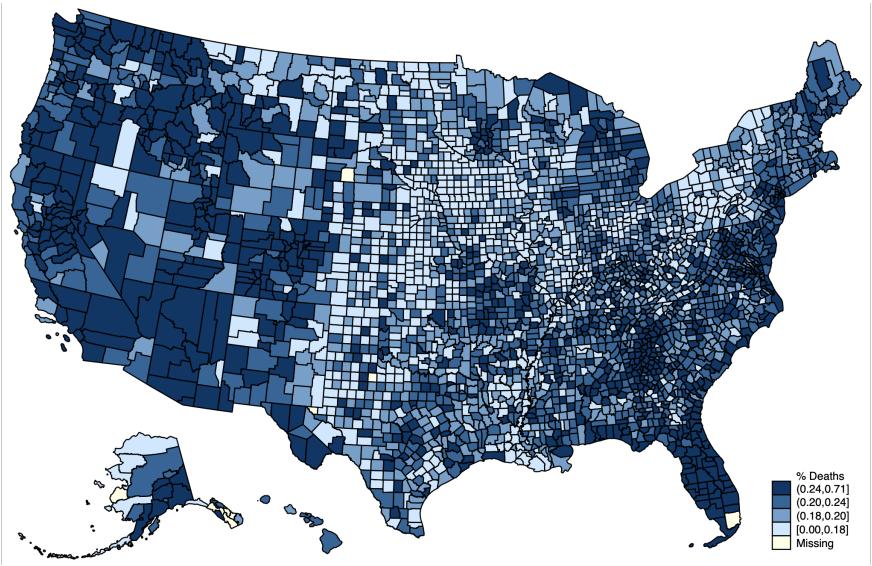


Figure C.2: Percent of Establishment Deaths from 2007-2009 by County



D Decomposition Derivations

$$\begin{aligned}
\theta^{\tau} - \theta^{\tau'} &\equiv \frac{\Delta E^{\tau}}{E_0^{\tau}} - \frac{\Delta E^{\tau'}}{E_0^{\tau'}} = \frac{\sum_i \Delta E_i^{\tau}}{\sum_i E_{i0}^{\tau}} - \frac{\sum_i \Delta E_i^{\tau'}}{\sum_i E_{i0}^{\tau'}} \\
&= \frac{\sum_i \theta_i^{\tau} E_{i0}^{\tau}}{\sum_i E_{i0}^{\tau}} - \frac{\sum_i \theta_i^{\tau'} E_{i0}^{\tau'}}{\sum_i E_{i0}^{\tau'}} \\
&= \frac{\sum_i \pi_i^{\tau} \theta_i^{\tau} E_{i0}}{\sum_i \pi_i^{\tau} E_{i0}} - \frac{\sum_i \pi_i^{\tau'} \theta_i^{\tau'} E_{i0}}{\sum_i \pi_i^{\tau'} E_{i0}} \\
&= \sum_i (\tilde{\pi}_i^{\tau} \theta_i^{\tau} - \tilde{\pi}_i^{\tau'} \theta_i^{\tau'}) E_{i0} \,, \qquad (6)
\end{aligned}$$

To separate this overall adjustment into within (W) and across (A) components, we expand the expression by subtracting and adding the average share $\tilde{\pi}_i \equiv \frac{\tilde{\pi}_i^{\tau} + \tilde{\pi}_i^{\tau'}}{2}$ on the right-hand side in the following way:

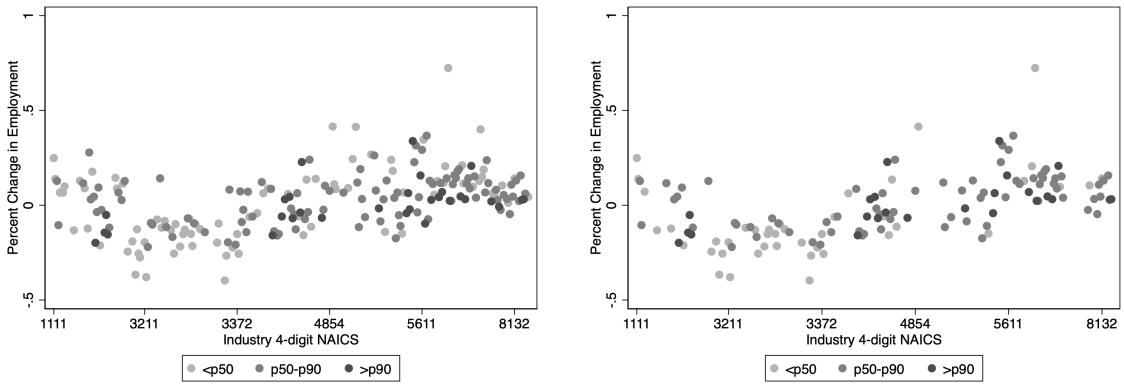
$$\theta^{\tau} - \theta^{\tau'} = \sum_i [\underbrace{\theta_i^{\tau}(\tilde{\pi}_i^{\tau} - \tilde{\pi}_i) - \theta_i^{\tau'}(\tilde{\pi}_i^{\tau'} - \tilde{\pi}_i)}_{\text{A}} + \underbrace{\tilde{\pi}_i(\theta_i^{\tau} - \theta_i^{\tau'})}_{\text{W}}] E_{i0} \,. \qquad (7)$$

Then, we simplify each component as follows:

$$\begin{aligned}
\theta_W^{\tau} - \theta_W^{\tau'} &\equiv \sum_i \tilde{\pi}_i (\theta_i^{\tau} - \theta_i^{\tau'}) E_{i0} \\
&= \sum_i \left(\frac{\tilde{\pi}_i^{\tau} + \tilde{\pi}_i^{\tau}}{2} \right) (\theta_i^{\tau} - \theta_i^{\tau'}) E_{i0} \\
&= \sum_i (\theta_i^{\tau} - \theta_i^{\tau'}) \left(\frac{(E_{i0}^{\tau}/E_0^{\tau}) + (E_{i0}^{\tau'}/E_0^{\tau'})}{2} \right) . \qquad (8)
\end{aligned}$$

$$\begin{aligned}
\theta_A^{\tau} - \theta_A^{\tau'} &\equiv \sum_i [\theta_i^{\tau}(\tilde{\pi}_i^{\tau} - \tilde{\pi}_i) - \theta_i^{\tau'}(\tilde{\pi}_i^{\tau'} - \tilde{\pi}_i)] E_{i0} \\
&= \sum_i \left[\theta_i^{\tau} \left(\frac{\tilde{\pi}_i^{\tau} - \tilde{\pi}_i^{\tau'}}{2} \right) - \theta_i^{\tau'} \left(\frac{\tilde{\pi}_i^{\tau'} - \tilde{\pi}_i^{\tau}}{2} \right) \right] E_{i0} \\
&= \sum_i \left(\frac{\theta_i^{\tau} + \theta_i^{\tau'}}{2} \right) (\tilde{\pi}_i^{\tau} - \tilde{\pi}_i^{\tau'}) E_{i0} \\
&= \sum_i \left(\frac{\theta_i^{\tau} + \theta_i^{\tau'}}{2} \right) \left(\frac{E_{i0}^{\tau}}{E_0^{\tau}} - \frac{E_{i0}^{\tau'}}{E_0^{\tau'}} \right) . \qquad (9)
\end{aligned}$$

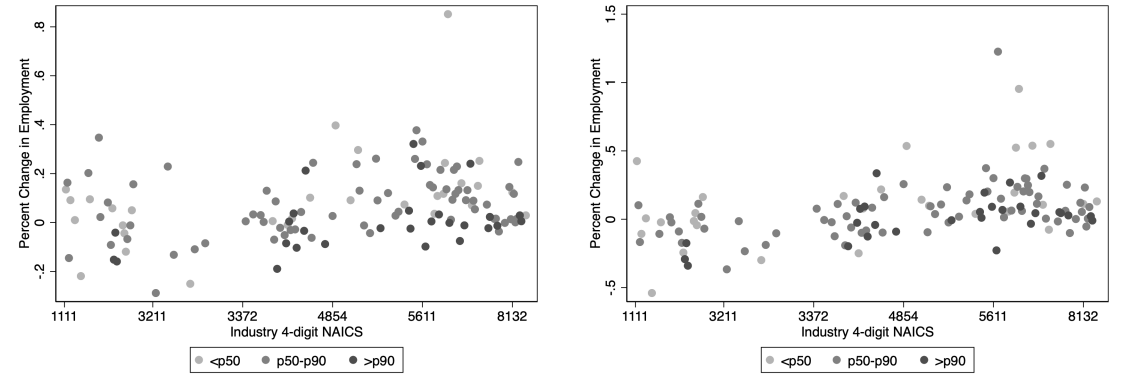
E Heterogeneous Effects by Industry



(a) No Correction (b) Holm Bonferroni

Figure E.3: Percent Change in Employment by Industry (2007-2009)

Notes: This figure shows the industry-level average percent change of employment from 2007 to 2009 using the full sample. Light gray points indicate industries below the median industry size (as measured by total employment in 2007), gray points indicate industries between the median and the 90th percentile of size, and dark gray points indicate the largest industries (above the 90th percentile of size). Panel (a) plots the average percent change in employment by industry that is statistically different than zero at the 10% level, while panel (b) applies the Holm-Bonferroni correction to adjust significance for multiple comparisons.



(a) White (b) Black

Figure E.4: Percent Change in Employment by Industry and Race (2007-2009)

Notes: This figure shows the percent change of employment from 2007 to 2009 inclusive for white and Black workers using the QWI sample and the Holm-Bonferroni correction. Light gray points indicate industries below the median industry size (as measured by total employment in 2007), gray points indicate industries between the median and the 90th percentile of size, and dark gray points indicate the largest industries (above the 90th percentile of size).

F Sensitivity Analysis and Goodness of Fit

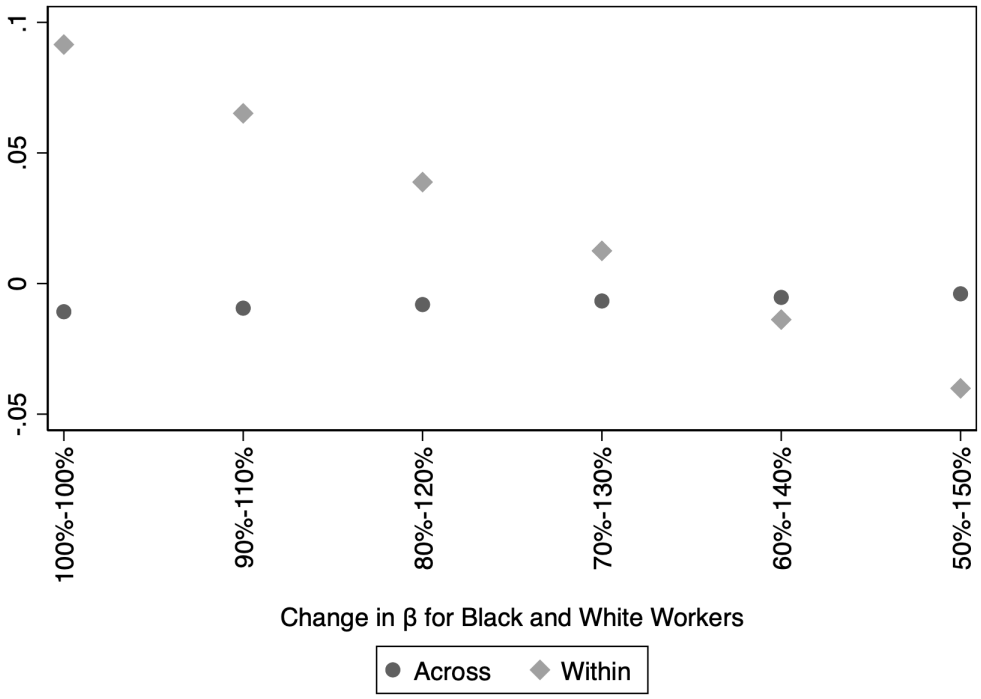


Figure F.1: Sensitivity of Estimated Within and Across Components to Changes in β^b and β^w

Notes: This figure shows the estimates of across and within components due to deaths when estimated coefficients of Black employment change are reduced stepwise by 10% and estimated coefficients of white employment change are increased stepwise by 10%.

Table F.1: Out-Of-Sample Fit by Race (White vs. Hispanic)

	(1) Mean Observed θ	(2) Mean Predicted θ	(3) Mean Difference	(4) SD of Difference
θ^w	-0.058	-0.058	-0.000	0.003
θ^h	-0.039	-0.038	-0.001	0.009
$\theta^w - \theta^h$	-0.019	-0.020	0.000	0.010
$[\theta^w - \theta^h]_A$	0.013	0.013	0.000	0.002
$[\theta^w - \theta^h]_W$	-0.032	-0.032	0.000	0.010

Notes: This table presents statistics related to the out-of-sample prediction outlined in Section 6. All statistics are based on 500 randomly-drawn estimation and holdout samples, stratified on county-level employment. Columns (1) through (3) present averages of estimates obtained for each random draw. Column (4) presents the standard deviation of Column (3).