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ABSTRACT

We estimate the magnitudes of reduced earnings, work hours, and wage rates of workers displaced during the Great Recession using linked employer-employee panel data from Washington State. Displaced workers' earnings losses occurred mainly because hourly wage rates dropped at the time of displacement and recovered sluggishly. Lost employer-specific premiums explain only 17 percent of these losses. Fully 70 percent of displaced workers moved to employers paying the same or higher wage premiums than the displacing employers, but these workers nevertheless suffered substantial wage rate losses. Loss of valuable specific worker-employer matches explain more than half of the wage losses.

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1 Introduction

Permanent loss of a long-term job—worker displacement—leads to earnings losses that are enduring, even permanent.[5] Longitudinal data on workers' earnings have established the magnitude of displaced workers' earnings losses, but little evidence exists on the reasons underlying these losses, which are important both theoretically and from the standpoint of mitigating the losses. In this paper we decompose earnings losses into changes in hourly wages and changes in work hours, and further decompose the changes in hourly wages into components attributable to employer effects (workers moving from higher- to lower-paying employers), match effects (the loss of valuable specific worker-employer matches), and a residual direct displacement effect that includes scarring due to job loss and the costs of lost seniority or any other aspect of wages that evolved over time in the previous employment relationship.

Job ladder models inspired by Burdett and Mortensen (1998) predict that on-the-job search will move workers to higher paying employers over their careers, with pay differences among firms representing differences in the division of surplus between workers and employers. Haltiwanger, Hyatt, Kahn, and McEntarfer (2018) find empirical support for the job ladder hypothesis, with workers tending to flow from low-wage to high-wage firms in job-to-job moves. In this framework, the typical displaced worker will experience wage losses due to employer effects, as he or she moves down the job ladder to a lower-paying employer.

[5] See, for example, Topel (1990), Jacobson, LaLonde, and Sullivan (1993a, 1993b), Farber (1993, 1997, 2015, 2017), Stevens (1997), von Wachter, Song, and Manchester (2009), Couch and Placzek (2010), Davis and von Wachter (2011), Jarosch (2015), Jung and Kuhn (2018), Krolikowski (2018), Fackler, Mueller, and Stegmaier (2017), Schmieder, von Wachter, and Heining (2018), and the reviews by Hamermesh (1996), Fallick (1996), Kletzer (1998), von Wachter (2010), and Carrington and Fallick (2017). Worker displacement has also been shown to reduce household expenditure (Stephens 2001), lead to poorer health (Schaller and Stevens 2015), reduce happiness (Kalil and DeLeire 2013), increase mortality (Sullivan and von Wachter 2009), and harm children affected by parental job loss (Oreopoulos, Page, and Stevens 2008; Stevens and Schaller 2011).

Worker-employer match effects encompass all time-invariant factors specific to an employment relationship that increase the value of a job match. Match effects may arise when a worker's skill set is intrinsically a good fit for a given employer's skill requirements, so the same worker has different productivity with different employers (Gibbons and Katz 1992). They may also arise as a result of the workings of internal labor markets (Doeringer and Piore 1971; Lazear 1992; Baker, Gibbs, and Holmstrom 1995a,b), where firm compensation policies prescribe wages that deviate from a worker's opportunity wage. For example, implicit contracts could have immediate (and time-invariant) effects on worker productivity and compensation. The match effects estimator we implement captures these time-invariant effects (sections 3.3 and 5.4).

A direct displacement effect implies that workers who lose their jobs experience wage loss irrespective of employer type or time-invariant quality of the previous job match. They could result from post-displacement wage penalties ("scarring") due to negative signaling or asymmetric information (Gibbons and Katz 1991). Direct effects may also result from features of internal labor markets that lead to wage growth with job tenure—seniority, delayed-payment contract, or the return to specific human capital—any of which could lead to wage losses after job displacement, independent of any change in employer wage premium or match quality.[6]

The decomposition of wages into these three components can be summarized by the equation $E[\Delta\ln(wage_{ijkt}) \mid displacement] = E[\Delta\psi_{ijkt}] + E[\Delta\mu_{ijkt}] + d$, where $\Delta\ln(wage_{ijkt})$ is the change in wages for displaced worker i who moves from employer j to employer k, $\Delta\psi_{ijkt}$ is the change in the employer wage premium, $\Delta\mu_{ijkt}$ is the change in the match-specific wage component, and d denotes the residual direct effect of displacement on wages.

[6] Note that the workings of internal labor markets can lead to either time-invariant or time-varying compensation patterns over the life of an employment relationship, and that both match effects and direct effects of displacement ultimately arise because workers and jobs are heterogeneous.

We use linked employer-employee panel data based on administrative records from the unemployment insurance (UI) system of Washington State during 2002–2014 to examine the sources of long-term earnings losses for displaced workers. To examine the role of employers in generating displaced workers' earnings losses we estimate employer-specific fixed effects, as suggested by Abowd, Kramarz, and Margolis (1999; hereafter AKM), then use these estimated employer effects to quantify whether displaced workers' losses result from displacement by employers who pay earnings premiums followed by reemployment with employers who do not. An extension of the AKM model suggested by Woodcock (2015) allows us to perform a similar exercise to examine the role of match effects.

In addition to allowing us to quantify the importance of employer effects in displaced workers' losses, the Washington administrative records are unusual because they report the quarterly paid work hours of all UI-covered workers in the state, not just quarterly earnings. The availability of both work hours and earnings allows us to calculate hourly wage rates on a quarterly basis, and to decompose displaced workers' long-term earnings losses into components due to reduced hours and lower hourly wages. The decomposition is important because we want to know whether the earnings losses of displaced workers who remain attached to the labor force result from an inability to find full-time work or from a drop in the return to their human capital.

Workers displaced in Washington during the Great Recession suffered earnings losses similar to those in Pennsylvania during the 1980s (Jacobson, LaLonde, and Sullivan 1993a, 1993b; hereafter JLS), in Connecticut during 2000–2001 (Couch and Placzek 2010; hereafter CP), and in the U.S. (nationally) over the 1980–2005 period (Davis and von Wachter 2011; hereafter DvW). Specifically, five years after job loss, displaced workers' earnings were 16

percent less than those of a stably employed comparison group.[7] A decomposition of these losses into hours and wage rates shows that virtually all earnings losses in the year following displacement resulted from lost work hours. But five years after displacement, only about 30 percent of lost earnings were due to reduced work hours, whereas about 70 percent were due to lower hourly wage rates. An unexpected finding is that the pattern of displaced workers' wage rate losses differ strikingly from that of earnings losses: whereas earnings follow a familiar pattern of "dip, drop, and partial recovery," wage rates drop suddenly at the time of displacement and recover far more sluggishly.

Overall, employer fixed effects played only a limited role in explaining these losses, accounting for about 9 percent of the average earnings losses of displaced workers five years after displacement, and for about 17 percent of average hourly wage rate reductions. Hence, employer premium losses, as measured by lost employer effects, were small. Two factors are behind the relative unimportance of employer fixed effects. First, only 30 percent of displaced workers moved to employers paying lower wage rate premiums, limiting the scope for fixed effects to play a role in displaced workers' losses. Second, the majority of displaced workers—those who moved to an employer paying the same or higher wage premium—suffered substantial wage rate losses that are perforce unrelated to employer wage premiums and must be attributed to other sources.

Moves down the job ladder are not a very important vehicle for wage rate losses after displacement, but changes in match effects are: They account for about 57 percent of wage rate reductions five years after displacement. The remaining 26 percent of the hourly wage reduction

[7] Like JLS and CP, we examine administrative data from a single state and a specific period, so we will draw frequent comparisons between their estimates and ours. Labor market conditions in Washington appear to have been similar to those nationally during the Great Recession (Appendix A.2), so we believe our estimates are informative and add to the evidence on displaced workers' losses, although they should not be heedlessly generalized.

can be attributed to the residual direct effect of displacement, the part unrelated to changes in employer effects or match quality. We conclude that match-specific factors are the main mechanism behind displaced worker wage losses, with direct displacement effects playing an important but secondary role.

The paper is organized as follows. Section 2 describes the data, and section 3 describes the empirical strategy. We extend JLS's seminal approach to a decomposition of earnings losses into components attributable to lost work hours and reduced wage rates. We then combine the JLS approach with the AKM model to examine the importance of employer effects and match effects in explaining displaced workers' losses. Section 4 presents the main results on earnings losses and their decomposition into lost work hours and reduced wage rates. Section 5 examines the role of employer effects, match effects, and direct effects in explaining displaced workers' losses and elaborates on why employer effects play a limited role. The final section reviews the estimates and discusses their implications. Appendix A describes additional analyses referred to in the main text, and Appendix B describes the AKM analysis underlying section 5's estimates.

2 Data

The data we use come from the records maintained by the Employment Security Department of Washington State to administer the state's UI system: quarterly earnings records from all UI-covered employers in Washington from 2002:I through 2014:IV; and the UI claims records of all individuals who claimed UI in Washington at any time during the same period.

The administrative earnings records of most states include a worker's quarterly earnings by employer; in addition, UI-covered employers in Washington are required to report each

worker's quarterly work hours.[8] Hence, a record appears for each quarter-worker-employer combination that includes the worker's earnings and work hours during the quarter with that employer. This allows us to construct an hourly wage rate in quarter *t* for most workers in Washington's formal labor market. We focus on the wage rate with the primary employer in each quarter (that is, the employer from whom the worker had the largest share of earnings in the quarter), dividing earnings from that employer by hours worked with that employer.[9]

Each worker's quarterly earnings record includes an employer identifier and the employer's four-digit North American Industry Classification System (NAICS) code, making it possible to construct employment at both the employer and industry level by summing over the records associated with a given employer or industry in each quarter. At the worker level, the linked employer identifiers and NAICS codes, along with the panel nature of the administrative records, allow us to observe worker transitions between employers. The panel nature of the earnings records also allows us to observe each worker's tenure with a given employer.

We use the Washington administrative records just described for two distinct analyses: an AKM analysis, which estimates individual employer and worker fixed effects for earnings, work hours, and wage rates using data on all UI-covered workers and employers in Washington; and an analysis of displaced workers' earnings losses, part of which makes use of the AKM analysis. In the rest of this section, we describe the sample used in the displaced worker analysis.

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[8] Washington is the only state that uses work hours in the year before claiming UI to determine UI eligibility, so employers are required to report hours, including overtime and hours of paid leave. Actual hours of salaried, commissioned, and piecework employees are reported unless those hours are not tracked, in which case employers are instructed to report 40 hours per week—see *Unemployment Insurance Tax Information*, Employment Security Department, Washington State, October 2014 (Revised). Our examination of the hours data starting in 2001 suggests they are reliable and of high quality—see Lachowska, Mas, and Woodbury (2018). For further discussion of Washington's UI system, see Lachowska, Meral, and Woodbury (2016).

[9] All earnings are converted to constant 2010 dollars using the Consumer Price Index for All Urban Consumers (CPI-U). We handle outliers by winsorizing positive earnings at the 99th percentile (about $69,000 per quarter), work hours at 2,000 hours per quarter, and wage rates at the 99th percentile (about $150 per hour).

Appendix B describes the dataset used in the AKM analysis, along with further discussion of the Washington administrative records and the AKM analysis itself.

2.1 Construction of the displaced worker analysis sample

We define a displaced worker by three criteria. First, a worker must have at least six years of job tenure (24 consecutive quarters of positive earnings) with the same primary employer during 2002–2007.[10] We refer to these as long-tenure workers. Second, we define a long-tenure worker as displaced if, at any time during 2008–2010,[11] that worker separated from her primary employer within four quarters of a quarter in which the employer experienced a mass layoff.[12] An employer is counted as having a mass layoff in a quarter during 2008–2010 if (i) employment dropped by 30 percent or more compared with the quarter of 2007 in which employment was greatest and (ii) maximum employment in 2007 was less than 130 percent of maximum employment in 2006. The latter condition helps to avoid classifying employers in steady decline as experiencing a mass layoff (DvW).[13,14]

Third, for all quarters starting with 2008:I, we require displaced workers to have at least one quarter per calendar year with positive earnings to remain in the sample. This follows JLS

[10] This criterion follows JLS and CP. In Appendix A.1, we describe estimates for displaced workers with shorter pre-displacement job tenures.
[11] We focus on separations during 2008–2010 because, although the Great Recession contraction officially lasted from December 2007 until June 2009, the recovery of the labor market lagged substantially: Washington's unemployment rate did not fall below 10 percent until June 2010, and had fallen only to 9.6 percent by December 2010. See Appendix A.2.
[12] A worker's displacement is dated to the quarter of his or her separation (not the quarter of the separating employer's mass layoff). Workers who separated, but not in connection with a mass layoff, are dropped from the displaced worker treatment group because, for these workers, the decision to separate is more likely to have been the result either of worker choice or employer selection.
[13] Because mass layoffs are defined by percentage changes in employment, small employers may be counted as having a mass layoff with only a small absolute change in employment. Accordingly, we drop any worker who at any time had a primary employer whose employment dropped below 50 workers in any quarter during 2002–2007.
[14] The data do not include an employer "successor file" for employers who have ceased to exist. Instead, we apply the worker-flow approach developed by Benedetto, Haltiwanger, Lane, and McKinney (2007) and drop displaced workers who appeared to separate in connection with an employer identification number change, merger, acquisition, spin off, or break up.

and implies that the estimates should be interpreted as effects of displacement on workers who remain attached to the Washington labor force.[15] (In Appendix A.3, we estimate the effects of displacement without imposing this requirement.)

The comparison group consists of long-tenure workers who were not displaced and who continued to have positive earnings with the same primary employer in every quarter from 2008:I through 2014:IV. The comparison, then, is between the outcomes of long-tenure displaced workers and long-tenure non-displaced (or "stably employed") workers who retain employment with the same primary employer for another seven years.[16,17]

For two reasons, we restrict the main analysis to workers who claimed UI at least once during 2002–2014. First, we observe demographic characteristics—age, gender, race, and education—only for this subset of workers (about 33 percent of the displaced workers).[18] Observing workers' characteristics allows us to make our analysis similar to previous research by restricting attention to displaced workers aged 20–50 at the time of displacement. Second, restricting attention to workers who claimed UI implies that all workers in the non-displaced comparison group experienced at least one UI-covered temporary layoff (with recall to the same employer) during the 2002–2014 period. [It is common for workers to receive UI benefits during

[15] Workers who drop out of the labor force, become self-employed, work in the underground economy, or move out of state will not appear in the Washington earnings records. (Self-employed workers are not covered by UI, underground earnings are not reported, and out-of-state earnings will be picked up in the earnings records of another state.)

[16] For estimates based on an alternative comparison group that need not remain with the same primary employer from 2008:I through 2014:IV, see Appendix A.4.

[17] We have conducted a robustness check that excludes the non-displaced co-workers of displaced workers from the comparison group. This exclusion drops about 20 percent of the original comparison group, and produces slightly larger estimates of displaced workers' earnings, hours, and wage rate losses.

[18] State UI agencies typically record workers' characteristics only when they claim UI. For gender and race, we assign an indicator with a constant value over the 13-year period. We assign the age of a worker in each quarter based on the worker's age in the quarter he or she was observed. For education, we assign a constant level if we observe the worker only once (that is, if he or she claimed UI more than once); however, if we observe the worker more than once , we assign the first observed value of education for all quarters until the quarter in which we observe a change.

temporary layoffs lasting less than one quarter (Anderson and Meyer 1994). The median UI claim duration of non-displaced workers in the sample we use was two weeks.] Selecting non-displaced workers who have experienced one or more temporary layoffs should result in a comparison group at greater risk of displacement, and hence more comparable to the displaced treatment group.[19]

2.2 Summary statistics for displaced workers and the comparison group

Table 1 displays descriptive statistics of variables for the full UI claimant sample (columns 1 and 2) and for the sample excluding workers in NAICS industries 51–56 (information, finance and insurance, real estate, professional, scientific, and technical services, management of companies; administrative, support, and waste management and remediation services—see columns 3 and 4). The full sample includes 2,690 displaced workers and 13,290 non-displaced workers.

In the pre-displacement years 2002–2005,[20] the displaced workers had somewhat higher quarterly average earnings and work hours, and higher hourly wage rates, than did the non-displaced comparison group (Table 1, top panel). This likely reflects a comparison group consisting of workers who experienced temporary layoff unemployment at some time. These differences nearly disappear when workers in NAICS industries 51–56 are dropped from the sample (columns 3 and 4). The demographic characteristics of the sample fit the well-known profile of displaced workers: 71 percent male, 78 percent white, 47 percent with a high school education but no post-secondary education, 11 percent with less than high school or a GED, and averaging almost 40 years of age.

The bottom panel of Table 1 shows two substantial differences between the displaced

[19] Appendix A.5 describes estimates using a broadened sample not restricted to UI claimants.
[20] We omit 2006–2007 to avoid including lower earnings and hours that may occur due to pre-displacement "Ashenfelter's dips."

worker treatment group and the non-displaced comparison group. First, the employers of displaced workers were smaller on average than those of non-displaced workers. This difference arises because, as noted in footnote 13, small employers are more likely than large employers to satisfy the definition of a mass layoff. Second, the distribution of displaced and non-displaced workers differs by major industry of employment in 2007:IV. About 82 percent of displaced workers came from just three major industries: NAICS codes 31–33 (manufacturing; 28 percent), 42–49 (trade; 16 percent), and 51–56 (described above; 38 percent). In contrast, only two-thirds of the non-displaced comparison group worked in these industries. The imbalance results mainly from NAICS industries 51–56, which employed 38 percent of the displaced workers, but only 6 percent of the non-displaced comparison group.

The composition of displaced workers in the Washington sample differs sharply from the composition of the Pennsylvania workers examined by JLS, 75 percent of whom came from manufacturing; however, the Connecticut sample analyzed by CP is more like the Washington sample: 16 percent from manufacturing, 19 percent from trade, and 23 percent from NAICS codes 51–56. (As a check on the estimates using all displaced workers, we estimate the losses of workers displaced from all industries except NAICS 51–56 in Appendix A.6.)

3 Estimation methods

We begin with a description of methods used to estimate earnings losses following displacement and to decompose those losses into components due to lost work hours and reduced hourly wage rates. We then describe the use of AKM methods to estimate the importance of employer effects and match effects in displaced workers' employment outcomes.

3.1 Estimated displacement effects on earnings, hours, and wage rates

To estimate displaced workers' earnings losses, we apply an estimator similar to JLS's multi-period difference-in-differences estimator, which compares the employment outcomes of displaced workers before, during, and after displacement with observationally similar long-tenure workers who were not displaced. The effect of displacement can be obtained by estimating a worker fixed-effects model of the following form:

$$Y_{ijt} = c_i + \gamma_t + \mathbf{Z}_{it}\boldsymbol{\theta}_1 + \mathbf{W}_{it}\boldsymbol{\theta}_2 + \mathbf{X}_{j(i,t)}\boldsymbol{\beta} + \sum_{k=-20}^{20}(\delta_k \cdot D_{itk}) + e_{ijt} \quad (1)$$

where Y_{ijt} is an employment outcome (earnings, hours, or wage rate) of worker i (with primary employer j) in quarter t; c_i is a worker-specific fixed effect; γ_t is a vector of calendar quarter indicators; $\mathbf{Z}_{it}$ includes the worker's age and age squared, and a vector of gender, race, and education indicators, interacted with the worker's age; $\mathbf{W}_{it}$ includes averages of the worker's pre-displacement (2002–2005) earnings and pre-displacement hours with the primary employer, both interacted with a vector of yearly indicators[21]; and $\mathbf{X}_{j(i,t)}$ consists of the characteristics of worker i's pre-layoff employer j (log of employer size and one-digit NAICS code in 2007:IV interacted with a vector of yearly indicators). Each D_{itk} is an indicator equal to one if the worker is observed in quarter k relative to displacement, zero otherwise ($k = 0$ is the quarter of displacement).[22]

Interest lies mainly in the estimates of δ_k, which are regression-adjusted differences in outcomes between displaced and non-displaced workers before ($k < 0$), at the time of ($k = 0$), and after ($k > 0$) the quarter of displacement. Interpreting the estimated δ_k as causal effects of displacement requires the assumption that, absent displacement, displaced workers' outcomes

[21] Similar interaction terms were used by DvW and are intended to control for differential earnings and hours trends.
[22] The omitted reference category consists of non-displaced workers and all observations recorded in quarters 21, 22, 23, and 24 before the displacement ($k < -20$); hence, we limit the analysis sample to observations recorded between –24 and 20 quarters relative to the quarter of displacement.

would have paralleled those of non-displaced workers. Given parallel trends, negative estimated δ_ks after displacement are taken as evidence of a displacement effect.[23]

Figure 1 illustrates the parallel-trends assumption using unconditional earnings and hours data for workers displaced in 2009:I and for workers who remained stably employed (that is, had the same primary employer throughout 2002–2014). During the first 5–6 years of the seven years before displacement, the earnings and hours of workers who will be displaced parallel those of workers who will remain stably employed. Also, the earnings and hours profiles in Figure 1 give a first impression that, following displacement, work hours come closer to recovering to their pre-displacement levels than do earnings.

3.2 Employer fixed effects

A growing body of research has examined the importance of employers in earnings determination and has shown that premiums paid by employers are an important component of earnings (e.g., Abowd, Kramarz, and Margolis 1999; Abowd, Creecy, and Kramarz 2002; Card, Heining, and Kline 2013; Card, Cardoso, and Kline 2016; Barth, Bryson, Davis, and Freeman 2016; Sorkin 2018; Song, et al. 2019). The Washington data allow us to construct a linked employer-employee panel of 22.9 million worker-year observations and estimate AKM models of earnings, hours, and hourly wages using data for 2002–2014—see Appendix B for details.[24] The resulting estimated employer fixed effects allow us in turn to observe the extent to which the earnings, hours, and wage rate losses of displaced workers result from working for post-displacement employers with policies regarding earnings, hours, and wage rates that differ systematically from the pre-displacement employer.

[23] As a robustness check of the parallel-trends assumption, we estimate a version of the model with worker-specific trends (a random trends model)—see Appendix A.7.
[24] As described in Appendix B, we omit both the sample of displaced workers and the comparison group when we estimate the AKM model.

The AKM models we estimate can be written:

$$\log Y_{ijt} = \alpha_i + \psi_{j(i,t)} + \theta_t + u_{ijt} \,, \tag{2}$$

where Y_{ijt} denotes earnings, hours, or the wage rate of worker i with employer j in year t; α_i is a worker-specific fixed effect (reflecting the productive characteristics of the worker that can be transferred among employers); $\psi_{j(i,t)}$ is an employer-specific fixed effect (reflecting employer characteristics that result in above- or below-average earnings, hours, or wage rates for all workers at employer j); θ_t is a vector of calendar year indicators; and u_{ijt} is the error component. The function $j(i,t)$ indexes the employer j effect for worker i in year t. Equation (2) applies to the full Washington labor market, and the administrative records available to us include demographic characteristics only for workers who claimed UI at some point during 2002–2014, so we cannot include demographics in equation (2).

Estimation of equation (2) for each of the three outcomes results in three vectors of estimated employer fixed effects ($\widehat{\psi}_j$), one each for the log of earnings, log of hours, and log of wage rates (all necessarily conditional on employment). Most generally, these fixed effects represent time-invariant policies of a given employer with respect to compensation—such as incentive pay, delayed compensation, and wage compression—or work hours (Baker, Gibbs, and Holmstrom 1994b; Lazear and Shaw 2009). A more specific interpretation, applicable only to earnings and wage rates (not hours), is that $\widehat{\psi}_j$ is a measure of the advantages derived from being employed by a given employer (Card, Heining, and Kline 2013). Still another interpretation, albeit somewhat controversial, is that $\widehat{\psi}_j$ is an estimate of employer j's position on a job ladder (Engbom and Moser 2017).[25]

[25] Interpretation of the employer fixed effect as a measure of an employer's position on the job ladder is consistent with Moscarini and Postel-Vinay's (2016) view of the job ladder as a stable ranking of jobs agreed upon by all

We treat the estimated employer fixed effects, $\widehat{\psi}_j$, as additional outcomes of the displacement process. The goal is to estimate the proportion of earnings, hours, and wage rate losses following displacement that can be attributed to a displaced worker's reemployment by an employer with a different $\widehat{\psi}_j$ than the employer from which she was displaced.[26] To do this, we assign the appropriate $\widehat{\psi}_j$s (for employer j) to each worker-quarter observation in the data, which is possible for all worker-quarter observations in the pre-displacement period (2002–2007) and to all but 643 worker-quarter observations in the post-displacement period.[27]

To estimate the importance of employer fixed effects in explaining the adverse outcomes of displaced workers, we regress the estimated $\widehat{\psi}$s (once each for earnings, hours, and wage rates) on pre- and post-displacement indicators, along the lines of equation (1):

$$\widehat{\psi}_{ijt} = c_i + \gamma_t + \mathbf{Z}_{it}\boldsymbol{\theta}_1 + \mathbf{W}_{it}\boldsymbol{\theta}_2 + \mathbf{X}_{j(i,t)}\boldsymbol{\beta} + \sum_{k=-20}^{20}(\delta_k \cdot D_{itk}) + e_{ijt} \quad (3)$$

The estimated δ_ks are regression-adjusted differences in employer effects realized by displaced workers relative to non-displaced workers and relative to before displacement. Equation (3)

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workers. However, Eeckhout and Kircher (2011) show that a structural model with worker-employer sorting does not produce a wage equation that is log-linear (or even monotone) in employer fixed effects. This limits the ability to interpret AKM employer effects as a ranking of firms, at least from the standpoint of their structural model. See also Bonhomme, Lamadon, and Manresa (2018) and Hagedorn, Law, and Manovskii (2017). Card, Cardoso, Heining, and Kline (2018, p. S44) provide an economic interpretation of the AKM employer effects as rents captured by inframarginal workers through asymmetric information about workers' reservation wages.

[26] Goldschmidt and Schmieder (2017) take a similar approach to estimating the loss of employer effects due to outsourcing of jobs, and Fackler, Mueller, and Stegmaier (2017) and Schmieder, von Wachter, and Heining (2018) examine employer effects for displaced workers. Fackler, Mueller, and Stegmaier (2017) focus on workers displaced in connection with employer bankruptcy. All use data on Germany.

[27] These 643 observations are from a total of 67,216 worker-quarter observations of displaced workers after displacement. The unmatched cases occur when the employer of a displaced worker was not in the connected set used to estimate the AKM $\widehat{\psi}_j$s. There are 118 such employers, who employed altogether 149 unique displaced workers for at least one quarter after displacement. If we estimate the AKM model using data only from the pre-displacement years (2002–2007), rather than from all available years (2002–2014), we are unable to match 17,499 worker-quarter observations for 1,424 unique displaced workers who were employed by 786 employers in the post-displacement period. For these 786 employers, $\widehat{\psi}_j$s could not be estimated either because they were not in the connected set or because they did not exist before 2008. (As with the 2002–2014 data, the 2002–2007 data produces $\widehat{\psi}_j$s for all pre-displacement employers.) The correlation coefficients between $\widehat{\psi}_j$s estimated using 2002–2014 data and $\widehat{\psi}_j$s estimated using 2002–2007 data are 0.97 for log earnings, 0.93 for log hours, and 0.95 for log wage rates.

includes individual worker fixed effects, so the estimated δ_ks represent within-worker changes in employer effects (for earnings, hours, and wage rates) following pre- to post-displacement employer transitions. For earnings and wage rates, negative estimated δ_ks represent evidence of lost employer-specific premiums. For hours worked, negative estimated δ_ks are evidence of reduced hours due to the differing working time policies of post-displacement employers.[28]

3.3 Match effects

As discussed in the introduction, worker-employer match effects occur when a worker's productivity differs among employers, either intrinsically, or through contractual arrangements that enhance a worker's productivity. We estimate time-invariant worker-employer match effects using Woodcock's (2015) fixed effects estimator, then use these estimated match effects to infer the portion of displaced workers' full losses that can be attributed to their loss.[29]

We implement Woodcock's method for each of the three outcomes (earnings, work hours, and wage rates). For each outcome, we net out the contribution of years of job tenure and year effects.[30] Then for each unique worker-employer match, we compute the average of the residualized outcome variable—denoted $\overline{\log Y}_{ij}$.[31] Finally, we estimate a model similar to the AKM model in equation (2), but using these within-match averages as dependent variables:

$$\overline{\log Y}_{ij} = a_i + \varphi_{j(i,t)} + \mu_{ij}, \tag{4}$$

[28] A possible alternative is to include employer fixed effects in equation (1), as in Schmieder, von Wachter, and Heining (2018). When we take this approach, we obtain results similar to those based on equation (3) and reported in section 4; that is, the employer dummies are weakly related to displaced workers' earnings losses. As Schmieder, von Wachter, and Heining point out, including employer fixed effects in equation (1) conditions on an outcome of displacement—employment by a given post-displacement employer—and could produce bias if characteristics of the post-displacement employer are correlated with unobserved determinants of displaced workers' losses. Accordingly, we prefer to model employer effects as an outcome of displacement, as in equation (3).

[29] See also the useful implementation of Woodcock's estimator by Sørensen and Vejlin (2013).

[30] Because job tenure is endogenous, we also perform the same exercise without adjusting for tenure—see Appendix A.10. The estimates are quite similar.

[31] Specifically, we first remove calendar-year effects from the outcome variable, then regress this adjusted outcome on years of job tenure and worker-employer match indicators. Finally, we compute within-match averages of the outcome after subtracting the contribution of job tenure from the outcome variable.

where a_i denotes the worker fixed effect, $\varphi_{j(i,t)}$ denotes the employer fixed effect, and μ_{ij} is an error, independent of individual worker and employer fixed effects. By definition, the vector of residuals from the estimated equation (4) represents the variation in $\overline{\log Y}_{ij}$ that remains after accounting for worker and employer fixed effects:

$$\hat{\mu}_{ij} = \overline{\log Y}_{ij} - \hat{a}_i - \hat{\varphi}_{j(i,t)}. \quad (5)$$

It follows that these residuals can be interpreted as estimated worker-employer match effects, averaged over the years we observe a given worker-employer match.

We estimate equation (4) using the same sample used to estimate the AKM model (as described in Appendix B), except that we retain displaced workers and the comparison group in the sample along with all other job movers. This is necessary because individual fixed effects for displaced workers need to be estimated in order to calculate their match effects ($\hat{\mu}$s)—see equation (5).[32] To estimate the effect of displacement on the estimated match effects, we use the $\hat{\mu}$s for log earnings, log hours, and log wage rates as dependent variables in equation (3); that is, we replace the employer fixed effects in equation (3) with the estimated match effects.

4 Estimated effects of displacement on earnings, work hours, and wage rates

This section describes estimates of the magnitude of displaced workers' earnings losses and decomposes those losses into their work-hour and hourly wage rate components.

4.1 Estimates of lost earnings

Figure 2 displays estimated effects of displacement on unconditional earnings (top) and log earnings (bottom) over a period of 5 years, and Table 2 summarizes the estimates for the quarter following displacement (Q1), eight quarters after displacement (Q8), and the average of quarters

[32] The estimated employer fixed effects (φ) from equation (4) are highly correlated with the estimated employer fixed effects (ψ) from the AKM model in equation (2); the correlation coefficients equal 0.984 for log wages, 0.988 for log earnings, and 0.995 for log hours.

17–20 following displacement (Q17–Q20).[33] The graphs are obtained by estimating equation (1) and plotting the estimated δ_ks, along with 95-percent confidence intervals (which are very small and at times hard to see). The vertical line in each graph marks the quarter of displacement; that is, the last quarter in which a displaced worker is observed with earnings or hours with the employer of the previous six years.

Soon-to-be-displaced workers' earnings drifted downward in roughly the year before displacement (Ashenfelter's dip), dropped sharply in the quarter of displacement and the quarter immediately after (quarters 0 and 1), then recovered, but never to their pre-displacement level, as gauged relative to earnings of the comparison group. The top graph in Figure 2 shows that, in the quarter following displacement, workers earned on average $6,531 less than non-displaced workers. Dividing this by pre-displacement (2002–2005) average earnings with the former primary employer ($13,349, from Table 1) implies a loss of about 49 percent in the quarter following displacement. The estimate in logs conditions on positive earnings and is somewhat smaller, suggesting a loss of about 42 percent [exp(–0.552) – 1] in the quarter after displacement.[34]

Figure 2 and Table 2 also show that, five years after displacement, workers earned on average $2,026 less per quarter from their primary employer than did comparable non-displaced workers, which translates to lost earnings of about 15 percent (dividing by $13,349). The log earnings estimates suggest long-term losses of about 16 log points.[35]

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[33] Columns 1 and 3 of Appendix Table A5 display the estimates on which Figure 2 is based. Zero values are dropped from the analysis when using outcomes in logarithmic form, resulting in an unbalanced panel.

[34] Inclusion of worker-specific trends in the model produces similar profiles of earnings, hours, and wage rates—see Appendix A.7.

[35] The estimates in Figure 2 and Table 2 are based on earnings from the primary employer only. If we instead use earnings from all employers, estimated earnings losses are similar, although somewhat smaller (see Appendix Table A5, columns 2 and 4). That is, accounting for the presence of multiple employers does not substantially change the conclusions drawn from focusing solely on outcomes from primary employers.

Table 3 compares the estimates in Figure 2 and Table 2 with those obtained by JLS, CP, and DvW, the studies most similar to ours. Where possible, we report estimates of earnings losses for both displaced UI claimants and for all displaced workers (in our case, the broadened sample discussed in Appendix A.5), along with the present discounted value (PDV) of average losses in terms of years of pre-displacement annual earnings.[36]

Using data on Pennsylvania UI claimants, JLS (1993b, Figure 5.5) estimated lost earnings of about 66 percent at the time of displacement, and about 24 percent six years later. Using data on Connecticut UI claimants, CP (Figure 4) estimated lost earnings of about 49 percent at the time of displacement, and about 32 percent six years later, implying about 1.7 years of lost pre-displacement earnings after six years. The earnings losses we estimate for Washington UI claimants displaced in 2008–2010 are smaller than those reported by either JLS or CP—about 16 percent and one year of lost pre-displacement earnings after five years—but in view of the differences in time and place, the similarities are perhaps more striking than the differences.[37]

For all displaced workers (not just UI claimants), JLS (1993b) estimate lost earnings of about 40 percent at the time of displacement, and about 25 percent six years later, implying about

[36] Following DvW, we use a 1.227 percent quarterly (5 percent annual) discount rate. The PDVs are computed using quarters 1–20 post displacement. The PDVs for CP's estimates are computed using estimates for quarters 1–24 reported in Web Appendix K of their paper and using a 1.227 percent rate. The PDV from JLS is computed as $50,000 (reported in Chapter 7 of their book) divided by pre-displacement earnings reported in Table 5.1. The figure from DvW, 2.5 years of pre-displacement earnings, is reported in Table 1 of their article.

[37] As noted in section 2.1, the comparison group for the UI claimant sample consists of workers who experienced at least one temporarily layoff during 2002–2014, likely attenuating the estimated displacement effects. JLS and CP compare the losses of UI claimants to all non-displaced, continuously employed workers. The JLS sample consisted largely of workers displaced from manufacturing in Pennsylvania during the decline of the U.S. steel industry, and the CP sample, although more diverse, consisted disproportionately of workers displaced from shipbuilding. No single industry in Washington imploded during the Great Recession, although Washington clearly experienced a severe contraction. Appendix A.2 compares the national unemployment rate with the unemployment rates in Washington, Connecticut, and Pennsylvania, during the years studied by us, CP, and JLS. The unemployment rate in Washington tracked the national rate more closely during the Great Recession than did the unemployment rates in Connecticut around the 2001 recession or in Pennsylvania around the dual recessions of the early 1980s.

2 years of lost pre-displacement earnings after six years. CP estimate lost earnings of about 33 percent at the time of displacement, and about 15 percent six years later, implying about 0.8 years of lost pre-displacement earnings after six years. The earnings losses we estimate for the broadened sample of Washington workers displaced in 2008–2010—1.1 years of lost pre-displacement earnings after five years—are similar to those reported by both JLS or CP.[38] [39]

Based on a much longer post-displacement period—20 years—DvW report that in a typical recession, the PDV of losses of the average displaced worker equal about 2.5 years of pre-displacement annual earnings. If we extrapolate the earnings losses of the Washington displaced claimants over 20 years post displacement, we find losses equal to about 2.5 years of pre-displacement earnings. For the broadened sample of displaced workers, we find losses equal to about 3.5 years of pre-displacement earnings.

4.2 Estimates of lost work hours and reduced hourly wage rates

Figure 3 displays estimated effects of displacement on unconditional work hours (top) and log hours (bottom), again based on equation (1).[40] As was true for earnings, the work hours of soon-to-be-displaced workers dip somewhat in roughly the year before displacement, drop greatly in the quarter of displacement and the following quarter, then partially recover. Although the recovery of work hours is more robust than the recovery of earnings, work hours of the displaced workers remain below those of the non-displaced comparison group five years after displacement.

[38] Unlike JLS and CP, our estimates of long-term earnings losses of UI claimants are smaller than those of the broadened sample (16 percent vs. 23 percent). Again, this is likely due to the comparison group consisting of workers who at some point were temporarily laid off. JLS and CP compare the losses of UI claimants to all non-displaced, continuously employed workers.

[39] Note that rate of recovery of earnings losses is more rapid for UI claimants (lower panel of Figure 2) than for the broader group of displaced workers (lower panel of Appendix Figure A11). This accounts for the small difference between the two groups in years of lost pre-displacement earnings (1 year vs. 1.1 years) compared with the larger difference between the two groups in earnings losses after five years (15 percent vs. 23 percent).

[40] The estimates underlying Figure 3 are shown in columns 1 and 3 of Appendix Table A6.

Specifically, hours lost in the quarter after displacement amount to 217 on a base of 519 hours (42 percent, estimated in levels, or 42 log points). The corresponding earnings losses are about 49 percent (in levels, or 55 log points), so lost work hours are responsible for roughly 76 percent (= 42/55) of lost earnings at the time of displacement. Five years after displacement (in quarters 17–20), the average displaced worker still works 14 fewer hours per quarter than otherwise (about 3 percent, estimated in levels, or 5 log points). The corresponding earnings losses are about 15 percent (in levels, or 16 log points), so reduced work hours account for about 28.8 percent (= 4.72/16.4) of the long-term earnings losses of displaced workers. As we confirm below, the remainder of long-term earnings losses are attributable to lower hourly wage rates.[41]

Qualitatively, these estimates are similar to work by Topel (1990) and Stevens (1997) using the Panel Study of Income Dynamics, which showed that reduced work time plays a relatively minor role in explaining the long-term losses of displaced workers. Several papers using German administrative data also show this pattern: Schmieder, von Wachter, and Bender (2009), Jarosch (2015), and Schmieder, von Wachter, and Heining (2018) find that five years after displacement, earnings losses are explained mainly by reduced daily wages rather than fewer days employed. (Days employed and the daily wage rate are the work time and wage rate measures available in German administrative data.)

It is also useful to examine displacement's effects on work hours at different points in the hours distribution. We do this using unconditional quantile regression (Firpo, Fortin, and Lemieux 2009) with a specification like equation (1). The dependent variable for each regression

[41] The estimates are consistent with Farber's (2017) finding that short-term movements from full-time to part-time employment explain part of the cost of displacement during and after the Great Recession. Farber's (1993, 2015, 2017) studies are based on the Displaced Worker Supplement to the Current Population Survey, so they pertain to a broader group of workers than those we are considering.

is the re-centered influence function transformation of quarterly work hours at a specified quantile. Figure 4 shows the estimated displacement effects (as proportional changes in quarterly work hours) at quantiles 10, 25, 50, 75, and 90.[42] Figure 4 also shows the estimated displacement effect on the probability of working a positive number of hours in each quarter, obtained using a linear probability model based on equation (1).

Figure 4 suggests that non-employment (i.e., a higher probability of 0 work hours) is not the driver of displaced workers' lost work hours. Displacement does reduce the probability of any work by about 2.5 percentage points in quarters 17–20, but this is a small reduction in proportional terms (0.025 on a base of 0.996). Rather, the main effect of displacement is a large reduction in the probability of hours worked at the 10th quantile (418 hours per quarter ≈ 32 hours per week) and more moderate reductions at the 25th and 50th quantiles (480 hours per quarter ≈ 37 hours per week; and 525 hours per quarter ≈ 40 hours per week). Because displacement implies lost seniority, which would imply a loss of overtime hours, it is surprising that displacement appears to lead to a modest *increase* in work hours at the 90th quantile.

Estimates of hourly wage rate losses due to displacement, based on equation (1), are displayed in Figure 5. Five years after displacement, hourly wage rates remained depressed by about 11.5 log points (top panel of Table 2). Comparing these wage loss estimates with those for earnings and hours implies that about 29 percent (4.7 log points) of the long-term earnings deficit of 16.4 log points were due to fewer work hours, and about 70 percent (= 11.5/16.4) to lower

[42] Proportional effects are obtained by dividing each estimated displacement effect by pre-displacement baseline hours at each quantile. Appendix Table A7 presents the point estimates and the baseline hours at each quantile.

hourly wage rates.[43] (An increase of 1.1 percent in the covariance between the log of work hours and the log of hourly wage rates accounts for the remaining earnings loss.)

The estimated hourly wage-loss profile in Figure 5 differs strikingly from both the earnings and work hour profiles (Figures 2 and 3). Following displacement, wage rates drop by about 13 log points and remain permanently lower by nearly 12 log points. (The sluggish recovery of wage rates is even more apparent in the broadened sample that includes workers who did not claim UI—see Appendix A.5.) In contrast, earnings and hours show notably more recovery after just two years.

5 Employer and match effects

Section 3.2 described an approach to estimating whether some portion of displaced workers' losses are due to employer fixed effects. For earnings or wage rates, this would imply loss of a job with an employer offering premium earnings or wage rates, and reemployment with an employer that did not. For hours worked, it would imply loss of a job with systematically longer hours than the job obtained after displacement. Section 3.3 described a way of estimating worker-employer match effects and the portion of displaced workers' losses due to loss of these effects. This section presents the results of both approaches. We first examine the overall importance of employer effects in generating displaced workers' reduced earnings, work hours, and wage rates (section 5.1). The estimates suggest that employer effects play a quite limited role overall, and we examine closely why this is the case in sections 5.2 and 5.3. Section 5.4 then presents our analysis of match and direct displacement effects.

[43] Figure 5 also shows a clear 8 log-point spike in hourly wage rates in the quarter of displacement (quarter 0). This spike results from a greater drop in work hours than in earnings in the quarter of displacement: for example, Figure 2 shows a drop in earnings of about 41 log points in quarter 0, whereas Figure 3 shows a drop in work-hours of about 47 log points. Payments for accumulated leave time (sick leave and vacation) and severance paid in the quarter of separation are the most likely cause of this pay bump. Severance payments are included with earnings in administrative earnings records and would inflate reported earnings relative to work hours in the quarter of separation, leading to an apparent increase in the hourly wage around the time of displacement.

5.1 Estimated average losses due to employer fixed effects

The three panels of Figure 6 show estimated displacement effects on employer fixed effects ($\widehat{\psi}_j$) for log earnings, log hours, and log of the hourly wage rate for the sample average displaced worker—see the time paths marked with circles, which plot the $\widehat{\delta}_k$s from equation (3). For comparison, the time paths marked with squares in Figure 6 repeat the estimated full effects of displacement on log earnings, log hours, and log hourly wage rate (from Figures 2, 3, and 5).[44]

For each of the three outcomes, lost employer effects explain a small (but statistically significant) fraction of the average losses following displacement—see the summary in row 2 of Table 2. In the quarter following displacement (Q1), 3.3 log points of the average earnings loss of 55 log points (6 percent) are due to working for an employer that pays less to all its workers, controlling for worker fixed effects. For work hours, differing employer hours policies account for 1.8 points of the overall 42 log-point loss (about 4 percent), and lost wage rate premiums account for 1.5 points of the overall 13 log-point reduction (about 11 percent).

Five years after displacement, the role of employer effects in explaining the lost earnings, hours, and wage rates of the average displaced worker remains minor. Specifically, employer effects account for 9 percent (1.5/16.4) of the overall 16.4 log-point earnings loss, virtually none of the 14.2 log-point hours loss, and 17 percent (2.0/11.5) of the 11.5 log-point reduction in hourly wage rates. Overall, employer effects are of relatively minor importance in explaining the average long-term losses from displacement.

The limited role of employer effects in explaining displaced workers' losses is surprising both because much recent research has found that employer effects are important to earnings

[44] The estimates underlying Figure 6 are reported in Appendix Table A8.

determination in general (notably Card, Heining, and Kline 2013; Card, Cardoso, and Kline 2016; Barth, Bryson, Davis, and Freeman 2016; Sorkin 2018; Song, et al. 2019) and because work by Schmieder, von Wachter, and Heining (2018) has found that lost employer-specific premiums almost wholly explain the losses of displaced workers in Germany. In Appendix A.8, we show that the small role for employer effects that we estimate does not result from differences between Schmieder, von Wachter, and Heining and us in sample selection or model specification. We can only speculate, but the greater importance of formal occupational training in Germany would be consistent with a reduced importance of job-specific effects (Acemoglu and Pischke 1998).

5.2 Transitions of displaced and non-displaced job changers

We can gain further insight into the losses of displaced workers—and why employer effects play such a limited role—by examining changes in the hourly wage rates of displaced workers as they transition to employers with different fixed effects (or premiums) for wages ($\widehat{\psi}$). For this analysis, we focus on changes in wage rates because reduced wage rates are mainly responsible for displaced workers' long-term earnings losses, although the analyses for changes in earnings and work hours point to similar conclusions—see Appendix A.9. We also examine the job transitions and associated changes in wage rates and employer effects of the 1.46 million "non-displaced job changers" who provide the variation allowing estimation of the AKM model described in Appendix B.

We first classify employers into quintiles by their AKM-estimated employer effects for wage rates.[45] We then assign the job transition of each displaced worker and each non-displaced

[45] The employer fixed effects come from the AKM analysis described in Appendix B and are based on the largest connected set from the 2002–2014 Washington data. Thresholds for the quintiles are obtained after sorting on worker-year records.

job changer to one of 25 quintile-to-quintile transition cells, based on the employer effect quintiles of each transition's origin employer and the destination employer two years later.[46] Specifically, we calculate the average change in wage rates and the associated change in employer effects for each of the 25 quintile-to-quintile transitions. We do this once for displaced workers and once for non-displaced job changers.[47] This results in a matrix for each group showing changes in wage rates and employer fixed effects associated with each inter-quintile transition.

Tables 4A and 4B show the results of this process for the hourly wage rates of displaced workers and non-displaced job changers, and Figure 7 illustrates the inter-quintile transition probabilities (as percentages) of displaced workers (top) and non-displaced job changers (bottom). Each quintile-*i* to quintile-*j* transition cell in Tables 4A and 4B contains five entries: (i) the percentage of workers who made the transition, (ii) the mean log-point change in hourly wages experienced by workers who made that transition, (iii) the mean change in the employer effect associated with the transition, (iv) the mean change in match effect associated with the transition, and (v) the mean direct effect associated with the transition. (We discuss the match effects and direct effects associated with each transition in section 5.4.) For example, 4.2 percent of displaced workers lost a job with a fourth-quintile employer and were employed two years later by a third-quintile employer. These workers on average suffered an earnings loss of 26.8

[46] For displaced workers, we focus on the transition from the pre-displacement employer to the employer two years after displacement, at which time 96 percent of displaced workers were employed. For non-displaced job changers, we select workers from 2008–2010 who had the same primary employer for at least two years, were observed with a different primary employer the following year, and remained with that primary employer for at least two years; see Card, Heining, and Kline (2013) for a similar event study. We have also produced results for non-displaced job changers using all available data—that is, transitions from 2004 through 2012. (Transitions starting in 2002–2003 and 2013–2014 cannot be used because we need to observe two years of job tenure before and after each transition.) The transition probabilities and associated changes in outcomes and employer effects for 2004–2012 are quite similar to those for 2008–2010.

[47] The pre-displacement wage rate is computed as an average over the pre-displacement years 2002–2005.

log points, 10.3 points of which could be attributed to lost employer effects, 6 points to lost match effects, and 10.4 point to direct displacement effects.

Three points are evident from Tables 4A and 4B. First, the distributions of transition probabilities for displaced workers and non-displaced job changers differ markedly—as illustrated in Figure 7. Whereas 42 percent of displaced workers originated with fifth-quintile employers, fewer than 10 percent originated in each of the bottom two quintiles (see the row sums in Table 4A). In contrast, roughly 20 percent of non-displaced job changers originated in each of the five employer effect quintiles (see the row sums in Table 4B). Also, over two-thirds (28.2/42.0) of the displaced workers originating in the fifth quintile moved to other fifth-quintile employers. In fact, moving from one fifth-quintile employer to another was the modal transition for displaced workers.

This observation leads to a second point: For both displaced workers and non-displaced job changers, within-quintile transitions were more common than moves to higher- or lower-quintile employers. To makes this clear, Table 5 shows sums and weighted averages of the below-diagonal, on-diagonal, and above-diagonal elements of Tables 4A and 4B. The "on-diagonal sums and averages" column shows that more than half of displaced workers and more than two-fifths of non-displaced job changers moved from one employer to another within the same quintile. A corollary is that, compared with non-displaced job changers, displaced workers were somewhat more likely to move to lower-quintile employers (30 percent versus 25.7 percent) and much less likely to move to higher-quintile employers (17.8 percent versus 32.4 percent).

Third, for the 30 percent of displaced workers who moved to lower-quintile employers, the loss of an employer-specific premium accounts for most of the wage loss: The average

displaced worker who moved to a lower-quintile employer suffered a wage rate loss of 29.3 log points, and nearly 19 points of this loss (64 percent) could be attributed to employer effects (Table 5). For displaced workers who moved to lower fixed effect employers, wage changes tended to move in parallel with employer effect changes.

Nevertheless, fully 70 percent of displaced workers moved to an employer in the same or a higher quintile, which implies that the typical displaced worker was not being knocked off a job ladder and starting again at the bottom. This is the case even though more than 60 percent of displaced workers lost jobs at fourth- or fifth-quintile employers and could potentially fall far. Rather, most displaced workers were reemployed with an employer paying a premium at least as large as the displacing employer's—but at a lower wage rate.

Figure 8A illustrates the point by plotting the inter-quintile changes in wage rates [$\Delta\ln(wage)$] and changes in employer effects ($\Delta\psi$) for displaced workers (triangles) and non-displaced job changers (circles). For non-displaced job changers, the fit of a linear regression of $\Delta\ln(wage)$ on $\Delta\psi$ is excellent ($R^2 = 0.997$) and suggests that a 0.25 log-point increase in the employer effect following a job change is associated with a 0.22 log-point increase in the wage rate. (The regression and standard regression statistics are in the note to Figure 8A.)

For displaced workers, the regression of $\Delta\ln(wage)$ on $\Delta\psi$ gives a looser fit ($R^2 = 0.824$) and suggests that a 0.25 log-point increase in the employer effect following job loss is associated with no change in the wage rate. Equally telling is that, according to the regression, a displaced worker who moves to an employer with the same fixed effect is expected to suffer a 0.17 log-point decrease in the wage rate.[48]

[48] Note also that, for non-displaced job changers, the correlation between inter-quintile changes in wage rates and changes in employer effects ($\Delta\psi$) is nearly perfect ($\rho = 0.998$); whereas for displaced workers, that correlation is less strong ($\rho = 0.908$).

The scatterplots and fitted regressions in Figure 8A suggest that the AKM model, with additive worker and employer effects, is a reasonable description of wage rate changes that accompany job mobility for non-displaced job changers: wage rate changes tend to match predicted changes following transitions across employers with different fixed effects. The close correspondence between wage changes and changes in employer fixed effects in the AKM sample is consistent with the symmetry test of Card, Heining, and Kline (2013). For displaced workers, the relationship between wage changes and changes in employer effects remains positive, but the relationship is no longer on the 45-degree line. Instead, it is shifted downward and has a flatter slope, implying smaller wage changes for a given quintile-to-quintile move, particularly for displaced workers who move upward.

5.3 Decomposing displaced workers' losses

It is helpful to use the data in Tables 4A and 4B (quintile-to-quintile transition probabilities, along with associated changes in wage rates and employer effects) to decompose displaced workers' average wage losses into portions attributable to (i) changes tied to employer effects accompanying transitions between quintile-*i* and quintile-*j* employers and (ii) losses not explained by employer effects following a quintile-*i* to quintile-*j* transition. Begin by writing the mean log change in the hourly wage rate of displaced workers as:

$$\overline{\Delta w}^{d} = \Sigma_i \Sigma_j m_{ij}^{d} \Delta w_{ij}^{d} \qquad (6)$$

where m_{ij}^{d} and Δw_{ij}^{d} denote transition probabilities and mean wage rate changes of displaced workers moving from quintile-*i* to quintile-*j* employers. This mean change can be decomposed by first adding then subtracting $\Sigma_i \Sigma_j m_{ij}^{d} \Delta \psi_{ij}^{d}$ on the right-hand side of equation (4):

$$\overline{\Delta w}^{d} = \Sigma_i \Sigma_j m_{ij}^{d} \Delta \psi_{ij}^{d} + \Sigma_i \Sigma_j m_{ij}^{d} \left(\Delta w_{ij}^{d} - \Delta \psi_{ij}^{d} \right) \qquad (7)$$

where $\Delta\psi_{ij}^{d}$ denotes the mean change in employer effects for wage rates of displaced workers moving from quintile-*i* to quintile-*j* employers. (Analogous decompositions can be written for changes in earnings and work hours; the data needed to calculate the decompositions appear in Appendix A.9. See Fortin, Lemieux, and Firpo [2011] for a comprehensive discussion of similar decompositions.)

The first term of the decomposition in equation (5) will be larger, the larger is the tendency of displacement to move workers from higher-quintile to lower-quintile employers—moves accompanied by lost employer effects. The second term will be larger, the larger are the gaps between the actual wage changes of displaced workers and the employer effect changes accompanying a given quintile-*i* to quintile-*j* move.

Results of the decompositions are summarized in Table 6. Consider the mean hourly wage loss of displaced workers two years after displacement—13.0 log points. If displaced workers' hourly wage changes had reflected only the differences between the wage premiums paid by their origin and destination employers, their hourly wages would have been lower by only 1.9 log points (less than 15 percent of the total).[49] The remaining loss of more than 11 log points represents an "excess" wage rate loss—greater than expected following transitions to employers paying different wage premiums than the origin employers. Movements to employers with different fixed effects can explain even less of displaced workers' earnings losses (10 percent) and work hour losses (less than 7 percent).

To summarize, employer fixed effects play a limited role in displaced workers' losses because the tendency of displaced workers to move to employers with lower fixed effects is

[49] Note that, five years after displacement, the mean hourly wage loss is slightly smaller and equals 11.5 log points; see Table 2. Table 2 also indicates that five years after displacement, employer effects account for a slightly larger share, 17.4 percent, of the losses (= 2.00/11.5).

modest: Fully 70 percent of displaced workers find reemployment with an employer in the same or a higher fixed effect quintile (see again Figure 7). The decompositions in Table 6 suggests that 85 percent of displaced workers' wage rate losses (and an even smaller percentage of earnings and hours reductions) stem from losses exceeding those explainable by changes in employer effects associated with job transitions.

5.4 Match effects and direct effects of displacement

The three panels of Figure 9 display the estimated effects of displacement on the match effects ($\hat{\mu}$) for log earnings, log hours, and log hourly wage rate, described in section 3.3. For comparison, the three panels also present the effects of displacement on log earnings, log hours, and log hourly wage rate overall (repeated from the lower panels of Figures 2, 3, and 5).

The estimates in Figure 9 suggest that on average, lost match effects play a major role in explaining reduced earnings and wage rates five years post-displacement (see also row 3 of Table 2). Specifically, the estimated match effects account for about 59 percent (= 8.48/16.4) of the overall 16 log-point long-term earnings loss, and 57 percent (= 6.54/11.5) of the overall 11.5 log-point reduction in long-term hourly wage rates. For long-term work-hour reductions (which are relatively small), match effects account for about 40 percent (= 1.88/4.72) of the overall 5 log-point loss.[50] The share of match effects in explaining earnings losses grows following displacement, suggesting that displaced workers do not find better matches over time.

Lost match effects account for the majority of the average displaced workers' losses, but they are less important for displaced workers who move to employers paying lower premiums than for the majority who move laterally or upward. This can be seen in Tables 4A and 5, and Figure 8B illustrates the point by plotting the relationship between changes in match effects ($\Delta\mu$)

[50] The match effects control for tenure. In Appendix A.10, we present estimates for match effects not accounting for tenure. The results are very similar.

and changes in employer effects ($\Delta\psi$) for displaced workers (triangles) and non-displaced job changers (circles). For displaced workers, the regression of $\Delta\mu$ on $\Delta\psi$ suggests that moving to an employer paying a premium that is higher by 0.25 log-point is associated with a match effect loss of 6–7 log points (see the regression in the note to Figure 8A). So for displaced workers who move up, lost match effects tend to offset increased employer premiums. For non-displaced job changers, the relationship between $\Delta\mu$ and $\Delta\psi$ is much weaker, as expected, because for these workers employer effects play a dominant role in explaining wage changes (Figure 8B).

The direct effects of displacement (d) show little systematic variation with moves across employers paying different premium levels ($\Delta\psi$). Figure 8C (and the fitted regression shown in the figure note) shows that displaced workers face average direct displacement losses of about 8–9 log points (the intercept), and the relationship between direct effects and $\Delta\psi$ is noisy and insignificant (both statistically and economically). The estimates suggest that direct displacement losses vary greatly among workers, but not systematically with respect to the type of job transition. Non-displaced job changers also face substantial direct penalties when they move: about 4–5 log points on average (the estimated intercept), and varying between about 2.5 log points for a worker with $\Delta\psi = -0.5$ and 6.5 log points for a worker with $\Delta\psi = +0.5$. So non-displaced job changers also face a cost of starting over, but on average it is about half that faced by displaced workers.

Figure 10 summarizes the sources of displaced workers' wage reductions over the five years following displacement. The direct effects of displacement are initially large, but they diminish over time, which makes sense because they include scarring effects and the loss of time-varying features of the former worker-employer relationship, such as lost seniority, value of specific human capital, or dissolution of a delayed payment contract. Lost match effects explain

the majority of wage losses after five years; that is, most of displaced workers' long-term wage reductions can be attributed to loss of the kind of time-invariant worker-employer match effect that Woodcock's method is intended to capture.

6 Discussion and Conclusions

The failure of displaced workers' earnings to recover to their pre-displacement trajectory is a consequence mainly of the sluggish recovery of hourly wage rates. At the time of displacement, wage rates drop by about 13 log points on average, and they remain nearly 12 log points below their pre-displacement level five years later (Figure 5). In contrast, paid hours drop by 42 log points at the time of displacement and rebound substantially (Figure 3). As a result, five years after displacement lower hourly wages account for 70 percent of displaced workers' earnings losses (section 4.2 and Table 2).

Figure 10 shows the division of displaced workers' hourly wage rate losses into the three components we have considered—employer effects, match effects, and direct displacement effects (see also Table 2). Overall, the loss of jobs with employers paying premiums accounts for only 17 percent of long-term reduced hourly wage rates; that is, lost employer-specific premiums (employer fixed effects) play a quite limited role, suggesting that displaced workers' losses should not be attributed mainly to lost employer-specific rents. In fact, fully 70 percent of displaced workers move to employers with similar or more favorable wage policies, yet despite their lateral or upward transitions, displaced workers generally experience lower wage rates. It follows that, for displaced workers, the evidence rejects the predictions of job ladder models.

The results may seem surprising in light of estimates using German data that have found an important role for employer fixed effects in explaining displaced workers' earnings losses (Fackler, Mueller, and Stegmaier 2017; Schmieder, von Wachter, and Heining 2018). However,

the relative unimportance of employer effects is consistent with findings from the macro-labor literature documenting the inability of job ladder models to account for long-term earnings losses (DvW; Jarosch 2015; Krolikowski 2017).[51]

As discussed in section 5, the failure of wage rates to recover is attributable mainly to the dissolution of favorable specific worker-employer relationships—see again Figure 10, which illustrates the 57 percent of displaced workers' long-term losses stemming from lost time-invariant match effects. These lost match effects seem difficult to explain in light of canonical search and matching models (Mortensen 1982; Pissarides 1985; Burdett and Mortensen 1998). Why doesn't job search over the subsequent five years lead to improved matches that eliminate the losses? A simple explanation is that long-tenure displaced workers had unusually good matches that were durable and long-lasting precisely because they were unusually valuable, consistent with Abraham and Farber (1987). The evidence suggests that finding an equally good match is a long and difficult process, especially in the aftermath of a recession.

The direct effects of displacement account for about 26 percent of displaced workers' long-term wage losses (Figure 10)—more important than employer effects, but less important than match effects. These direct effects may come from "scarring" (negative signaling or asymmetric information) or from the dissolution of implicit contracts that both shield a worker from the outside labor market and bind a worker and employer in a relationship that enhances the value of that relationship. These contracting mechanisms include seniority systems, specific human capital investment, and delayed-payment contracts, all of which lead to wage growth over the life of a job. They represent the time-varying aspects of the specific worker-employer relationship that are lost with displacement. Direct displacement effects—the effects of starting

[51] Also, Moore and Scott-Clayton (2018) have replicated parts of our analysis using Ohio administrative data, and find that employer fixed effects play a minor role in explaining displaced workers' losses.

over—explain most of the early wage loss of displaced workers, but diminish over time, consistent with concavity of the tenure-wage profile as well as diminishing effects from scarring.

The evidence suggests that most displaced workers were especially well matched with an employer over many years. Displacement ended the match and eliminated the value created by the relationship. As Jacobson, LaLonde, and Sullivan (1993, p. 706) speculated based on their estimates, "something intrinsic to the employment relationship itself … is lost when workers are displaced." Finding a limited role for employer effects, and a more important role for job specific match effects, allows us to be more confident about the accuracy of this conjecture.

Commenting on DvW, Robert Hall (2011, p. 56) remarked that "if workers who are highly paid relative to their productivity suffer layoffs and are immediately hired elsewhere at normal wages and the same productivity, it is a private loss—a transfer of rents—but not a social loss." The importance of match effects, and possibly scarring, in explaining post-displacement wage losses suggests a large portion of these losses likely represents a social loss.

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Table 1
Sample descriptive statistics

	(1)	(2)	(3)	(4)
	UI claimant sample		UI claimant sample excluding NAICS 51–56[1]	
	Displaced	Non-displaced	Displaced	Non-displaced
Quarterly average earnings, hours, and wage rates, 2002–2005				
Earnings (2010 dollars)	13,349	12,482	12,440	12,135
	(6,466)	(5,996)	(6,259)	(5,490)
Paid work hours	519	500	509	500
	(82)	(95)	(85)	(97)
Hourly wage rate (2010 dollars/hour)	58.00	51.22	51.84	49.49
	(43.12)	(38.96)	(39.04)	(37.69)
Worker characteristics, 2007:IV				
Female (proportion)	0.286	0.359	0.271	0.353
Race (proportions)				
White, not Hispanic	0.779	0.677	0.749	0.671
Black, not Hispanic	0.030	0.033	0.027	0.032
Hispanic	0.073	0.133	0.101	0.139
Asian/Pacific Islander	0.071	0.100	0.073	0.100
American Indian or Alaskan Native	0.013	0.014	0.014	0.015
Missing, unknown, or not available	0.035	0.044	0.034	0.044
Schooling (proportions)				
less than high school	0.080	0.129	0.104	0.135
GED	0.031	0.032	0.036	0.033
high school graduate	0.465	0.462	0.471	0.472
some college	0.149	0.161	0.152	0.158
associate's degree	0.124	0.101	0.127	0.102
bachelor's degree	0.125	0.093	0.094	0.081
master's/PhD	0.026	0.023	0.016	0.019
Age (years)	39.45	41.47	38.92	41.53
	(6.46)	(6.44)	(6.56)	(6.44)
Employer characteristics in 2007:IV				
Employer size (number of workers)	2,042	8,478	824	8,400
	(2,578)	(20,065)	(1,550)	(20,317)
NAICS Industry (proportions)				
11 agriculture, forestry, fishing	0.016	0.045	0.025	0.048
21–23 mining, utilities, construction	0.088	0.082	0.141	0.087
31–33 manufacturing	0.277	0.460	0.445	0.491
42–49 trade, transportation	0.160	0.145	0.258	0.155
51–56 information, finance, prof. services	0.377	0.063	n/a	n/a
61–62 educational and health care services	0.013	0.093	0.020	0.099
71–72 arts, recreation, hospitality services	0.055	0.032	0.088	0.034
81 other services	0.007	0.006	0.011	0.006
92–99 public administration and unclassified	0.007	0.075	0.012	0.080
Number of employers (pre- and post-displacement)	3,493	1,570	501	1,383
Number of workers	2,690	13,290	1,676	12,447

Notes: Standard deviations in parentheses. Categorical variables displayed in the table are mutually exhaustive, but due to rounding errors may not add to 100 percent.
1. NAICS industries 51–56 include information, finance and insurance, real estate, professional, scientific, and technical services, management of companies; administrative, support, and waste management and remediation services.
Source: Authors' tabulations of Washington administrative wage and claims records. See section 2.1 for details of the sample construction.

Table 2
Summary of estimated quarterly losses at different quarters following displacement

	Earnings			Hours			Hourly wage rate ($)		
	Q1	Q8	Q17–Q20	Q1	Q8	Q17–Q20	Q1	Q8	Q17–Q20
1. Full losses of displaced workers (sections 4.1 and 4.2)									
log change	–0.552	–0.256	–0.164	–0.423	–0.117	–0.047	–0.134	–0.140	–0.115
level change	–$6,531	–$2,817	–$2,026	–217	–47.5	–14.2	–2.40	–2.82	–2.86
as % of base	–48.9	–21.1	–15.2	–41.8	–9.2	–2.7	–4.1	–4.9	–4.9
2. Changes due to employer fixed effects (section 5.1)									
log change	–0.033	–0.022	–0.015	–0.018	–0.007	0.005	–0.015	–0.015	–0.020
% of full losses	6.0	8.6	9.1	4.3	6.0	0.0	11.2	10.7	17.4
3. Changes due to lost match effects (section 5.4)									
log change	–0.062	–0.082	–0.085	–0.038	–0.027	–0.019	–0.024	–0.055	–0.065
% of full losses	11.2	32.0	51.8	9.0	23.1	40.4	17.9	39.3	56.5
4. Direct displacement effects (section 5.4)									
log change	–0.447	–0.152	–0.064	–0.376	–0.083	–0.033	–0.095	–0.070	–0-030
% of full losses	82.8	59.4	39.0	86.8	70.9	59.6	70.9	50.0	26.1

Notes: Entries in panel 1 give estimated displacement effects on the indicated outcome in quarter 1 (Q1), quarter 8 (Q8), or the average of quarters 17, 18, 19, and 20 (Q17–Q20) following displacement. For the level changes in panel 1, implied percentage changes relative to the non-displaced comparison group are shown in the "as % of base" row. (For example, the estimated effect of displacement on average earnings in quarters 17–20 after displacement is –$2,026, which is 15.2 percent less than the earnings of the non-displaced comparison group.) Panels 2, 3, and 4 show losses due to employer effects, match effects, and direct displacement effect as log points as a percentage of full displacement losses. [For example, the percentage of full Q1 earnings losses accounted for by lost employer fixed effects is (–0.033/–0.552) × 100 = 6.0%.]
Source: Summary of estimates displayed in Figures 2, 3, 5, 6, and 9.

Table 3
Estimated earnings losses due to displacement, selected studies using UI administrative records

Study	Region and time period	Sample	First year earnings losses	Long-term earnings losses	PDV of losses / pre-displacement annual earnings
Jacobson, Lalonde, and Sullivan (1993b)	Pennsylvania, 1974–1986	All UI claimants	66%	24% at 6 years	not reported
	Pennsylvania, 1974–1986	All workers	40%	25% at 6 years	2 years after 6 years
Couch and Placzek (2010)	Connecticut, 1993–2004	All UI claimants	49%	32% at 6 years	1.7 years after 6 years
	Connecticut, 1993–2004	All workers	33%	15% at 6 years	0.8 year after 6 years
Davis and von Wachter (2011)	United States, 1974–2008	All workers	39% in recessions	20% at 20 years	2.5 years after 20 years
Lachowska, Mas, and Woodbury (2019)	Washington, 2002–2014	All UI claimants	49%	15% at 5 years	1 year after 5 years 2.5 years after 20 years
	Washington, 2002–2014	Broadened sample (Appendix A.5)	45%	23% at 5 years	1.1 years after 5 years 3.5 years after 20 years

Notes: Percentage estimates for Jacobson, LaLonde, and Sullivan (1993b, Figure 5.5) are reported in Couch and Placzek (2010, Table 1 and Web Appendix K). For Couch and Placzek, PDVs of losses are calculated using point estimates for quarters 1–24 post-displacement shown in Web Appendix K, then applying a 5 percent annual (1.227 quarterly) discount rate. For Lachowska, Mas, and Woodbury, PDVs of losses are calculated using point estimates for quarters 1–20 post-displacement, then applying a 5 percent annual (1.227 quarterly) discount rate. The 20-year losses are calculated by extrapolating the Q20 earnings loss out to year 20 and discounting.

Table 4A
Displaced workers' inter-quintile employer transitions, wage rate changes, employer effect changes, match effect changes, and direct displacement effects, 2008–2010

Fixed-effect quintile of origin employer		Fixed-effect quintile of destination employer					Row sums and weighted means
		1	2	3	4	5	
1	% of displaced workers in cell	5.0	2.0	1.1	0.9	0.8	9.9
	mean Δ wage	-16.9	-21.1	-3.4	-10.8	29.0	-11.7
	mean Δ employer effect	-1.1	10.8	23.4	37.6	56.4	12.5
	mean Δ match effect	-7.5	-16.3	-20.1	-32.8	-17.3	-13.8
	mean direct effect	-8.3	-15.6	-6.7	-15.7	-10.1	-10.4
2	% of displaced workers in cell	2.0	3.9	1.8	1.3	0.4	9.4
	mean Δ wage	-44.7	-9.9	-10.3	6.4	3.1	-14.6
	mean Δ employer effect	-19.9	-0.7	9.2	21.1	40.3	2.0
	mean Δ match effect	-6.3	-4.3	-10.6	-11.3	-28.3	-8.0
	mean direct effect	-18.4	-4.9	-9.0	-3.3	-8.9	-8.5
3	% of displaced workers in cell	1.9	4.1	7.4	2.9	2.8	18.9
	mean Δ wage	-36.6	-28.1	-19.7	-9.3	0.3	-18.7
	mean Δ employer effect	-29.9	-11.7	-0.9	10.7	30.4	0.3
	mean Δ match effect	-2.0	-9.1	-7.8	-11.5	-13.0	-8.8
	mean direct effect	-4.7	-7.4	-11.0	-8.5	-17.1	-10.1
4	% of displaced workers in cell	1.5	2.6	4.2	7.8	3.8	19.8
	mean Δ wage	-55.4	-37.2	-26.8	-8.6	7.4	-16.6
	mean Δ employer effect	-40.5	-21.3	-10.3	-1.2	20.1	-4.6
	mean Δ match effect	-6.4	-8.4	-6.0	-2.3	-4.5	-4.6
	mean direct effect	-8.4	-7.5	-10.4	-5.1	-8.2	-7.4
5	% of displaced workers in cell	0.4	2.1	2.8	8.5	28.2	42.0
	mean Δ wage	-50.5	-48.2	-25.5	-14.6	-1.8	-8.8
	mean Δ employer effect	-50.3	-36.8	-26.1	-10.7	0.7	-5.8
	mean Δ match effect	10.0	-3.3	1.4	0.0	-0.4	-0.2
	mean direct effect	-10.2	-8.1	-0.8	-4.0	-2.1	-2.8
Column sums and weighted means	% of displaced workers	10.8	14.6	17.3	21.3	36.0	100.0
	mean Δ wage	-32.0	-26.9	-20.3	-10.3	0.1	-13.0
	mean Δ employer effect	-16.8	-11.1	-4.6	-0.4	6.8	-1.9
	mean Δ match effect	-5.5	-7.8	-7.0	-4.4	-2.5	-4.8
	mean direct effect	-9.7	-7.9	-8.7	-5.4	-4.2	-6.4

Notes: This transition matrix shows the movement (and associated outcomes) of displaced workers between employers with different fixed effects for wage rates. Employers are classified into quintiles by their AKM-estimated fixed effects for wage rates. (Thresholds for quintiles are obtained by sorting on worker-year records.) The elements of each five-element cell show (i) the percentage of all displaced workers making the given quintile-to-quintile transition, (ii) the mean log-point change in hourly wage rates of those making that transition, (iii) the mean employer effect change associated with that transition; (iv) the mean match effect change associated with that transition, and (v) the mean direct displacement effect associated that transition. Figures are based on a comparison of employment two years before and after displacement. See the text for further discussion.
Source: Authors' calculations based on the displaced worker sample described in the text, and on employer effects estimated for the sample described in Appendix B.

Table 4B
Non-displaced job changers' inter-quintile employer transitions, wage rate changes, employer effect changes, match effect changes, and direct transition effects, 2008–2010

Fixed-effect quintile of origin employer		Fixed-effect quintile of destination employer					Row sums and weighted means
		1	2	3	4	5	
1	% non-displaced job changers	10.2	4.5	3.0	2.1	1.0	20.7
	mean Δ wage	-4.3	12.2	21.5	32.2	51.9	9.3
	mean Δ employer effect	-3.3	15.3	26.6	38.3	58.2	12.1
	mean Δ match effect	3.3	0.9	-1.0	-1.0	1.3	1.6
	mean direct effect	-4.3	-4.0	-4.1	-5.1	-7.6	-4.5
2	% non-displaced job changers	4.2	5.5	4.2	2.8	1.6	18.3
	mean Δ wage	-13.0	-1.0	6.7	16.5	36.6	4.0
	mean Δ employer effect	-14.7	-0.6	9.6	21.7	42.8	5.7
	mean Δ match effect	4.2	3.1	1.8	1.0	2.4	2.7
	mean direct effect	-2.5	-3.5	-4.7	-6.2	-8.6	-4.4
3	% non-displaced job changers	2.1	4.1	6.1	6.0	2.3	20.8
	mean Δ wage	-22.9	-8.1	-0.3	7.8	24.2	0.9
	mean Δ employer effect	-27.3	-10.6	-0.3	9.4	30.3	1.1
	mean Δ match effect	6.5	5.3	3.2	1.6	1.4	3.3
	mean direct effect	-2.1	-2.7	-3.2	-3.1	-7.5	-3.4
4	% non-displaced job changers	1.3	2.4	4.0	8.0	4.9	20.6
	mean Δ wage	-35.8	-18.6	-9.6	-0.2	14.0	-2.9
	mean Δ employer effect	-39.0	-22.1	-11.0	-0.1	17.2	-3.0
	mean Δ match effect	6.8	7.7	5.5	3.3	3.2	4.4
	mean direct effect	-3.6	-4.2	-4.0	-3.3	-6.4	-4.3
5	% non-displaced job changers	0.6	1.4	1.7	3.9	12.2	19.7
	mean Δ wage	-58.1	-39.8	-28.6	-14.3	0.1	-9.7
	mean Δ employer effect	-59.6	-42.7	-30.3	-16.0	1.6	-9.5
	mean Δ match effect	5.1	6.3	6.0	6.4	2.4	3.9
	mean direct effect	-3.6	-3.4	-4.4	-4.7	-3.9	-4.0
Column sums and weighted means	% non-displaced job changers	18.4	17.9	18.9	22.8	22.0	100.0
	mean Δ wage	-12.3	-4.7	0.2	4.5	10.7	0.33
	mean Δ employer effect	-12.8	-5.1	1.1	5.8	13.7	1.28
	mean Δ match effect	4.2	3.9	3.0	2.7	2.4	3.17
	mean direct effect	-3.6	-3.5	-3.9	-4.0	-5.3	-4.1

Notes: This transition matrix shows the movement (and associated outcomes) of non-displaced job changers between employers with different fixed effects for wage rates. Employers are classified into quintiles by their AKM-estimated fixed effects for wage rates. (Thresholds for quintiles are obtained by sorting on worker-year records.) The elements of each five-element cell show (i) the percentage of all non-displaced job changers making the given quintile-to-quintile transition, (ii) the mean log-point change in hourly wage rates of those making that transition, (iii) the mean employer effect change associated with that transition; (iv) the mean match effect change associated with that transition, and (v) the mean direct displacement effect associated that transition. Figures are based on a comparison of employment two years before and after a job change. See the text for further discussion.
Source: Authors' calculations based on the primary job changes taking place during 2008–2010 in the AKM sample described in Appendix B, and on employer effects estimated for the sample described in Appendix B.

Table 5
Below-, on-, and above-diagonal sums and weighted averages of inter-quintile transitions of displaced workers and non-displaced job changers, 2008–2010

	Below-diagonal sums and means	On-diagonal sums and means	Above-diagonal sums and means
% of displaced workers	30.0	52.2	17.8
mean Δ wage	-29.3	-7.4	-2.1
mean Δ fixed effect	-18.8	-0.1	21.4
mean Δ match effect	-3.6	-2.7	-13.0
mean direct effect	-6.9	-4.6	-10.6
% of non-displaced job changers	25.7	42.0	32.4
mean Δ wage	-17.8	-1.2	16.7
mean Δ fixed effect	-20.1	-0.5	20.5
mean Δ match effect	5.8	3.0	1.3
mean direct effect	-3.5	-3.7	-5.1

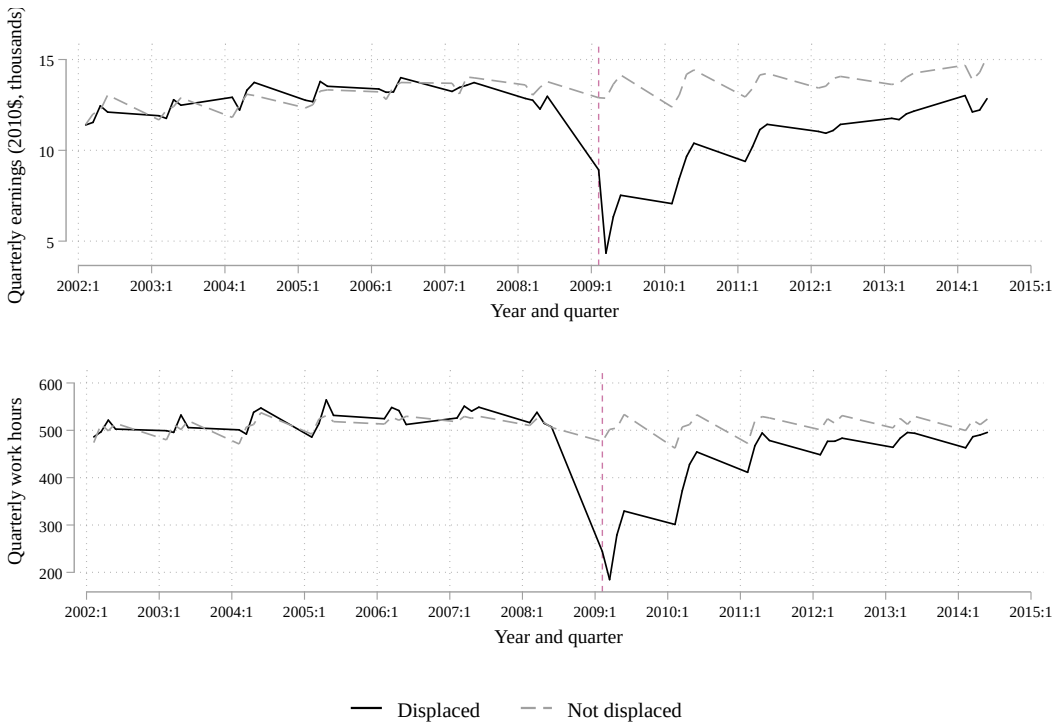
Notes: Figures in the "Below-diagonal sums and averages" column show sums (or weighted means of) the cells in transition matrices in the Tables 4A and 4B representing moves to an employer with a lower-quintile fixed effect for wage rates. Figures in the "On-diagonal" and "Above-diagonal" columns show sums or weighted means of the cells in the transition matrices representing moves to a same-quintile employer, or to a higher-quintile employer. Figures for both displaced workers and non-displaced job changers are based on a comparison of employment two years before and after displacement or job change.
Source: Authors' calculations from data in Tables 4A and 4B.

Table 6
Displaced workers' losses two years after displacement decomposed into portions attributable to (i) fixed effect changes from transitions to new employers and (ii) losses exceeding those expected due to fixed effect changes

Outcomes (log points)	Mean loss of displaced workers	Portion attributable to: fixed effect changes from job transitions	Portion attributable to: losses exceeding fixed effect changes	Percentage attributable to transitions
earnings	–28.9	–2.9	–26.0	10.0
work hours	–16.1	–1.1	–15.0	6.8
hourly wage rates	–13.0	–1.9	–11.2	14.6

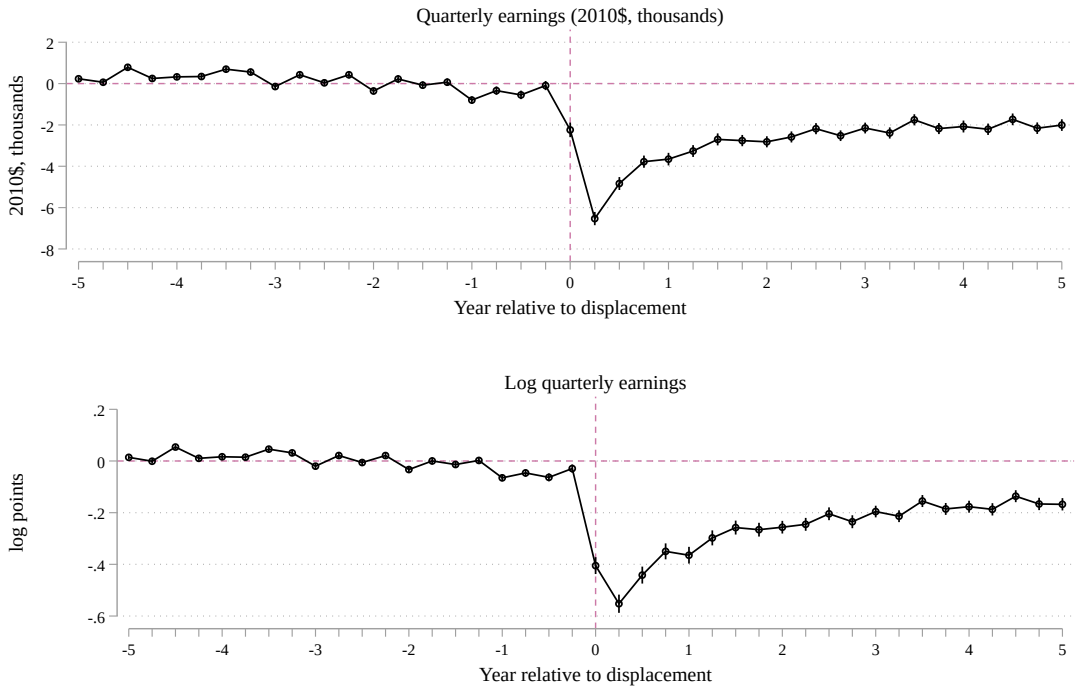
Notes: The table decomposes the mean losses of displaced workers into portions attributable to (i) transitions to employers with different fixed effects and (ii) differences (larger losses or smaller gains) between the changes actually experienced by displaced workers and the employer fixed effect changes that would be expected based on the transitions they made. For example, displaced workers experienced an average wage rate loss of 13.0 log points, and 1.9 log points (14.6 percent) occurred because displaced workers tended to move to employers with lower fixed effects. The remaining 11.2 points of the average loss occurred because displaced workers had larger losses (or smaller gains) than would be expected based on their transitions to new employers.
Source: Authors' calculations based on data in Tables 4A and 4B.

Figure 1
Earnings (top) and hours (bottom) profiles of displaced and stably employed workers, Washington State, 2009Q1



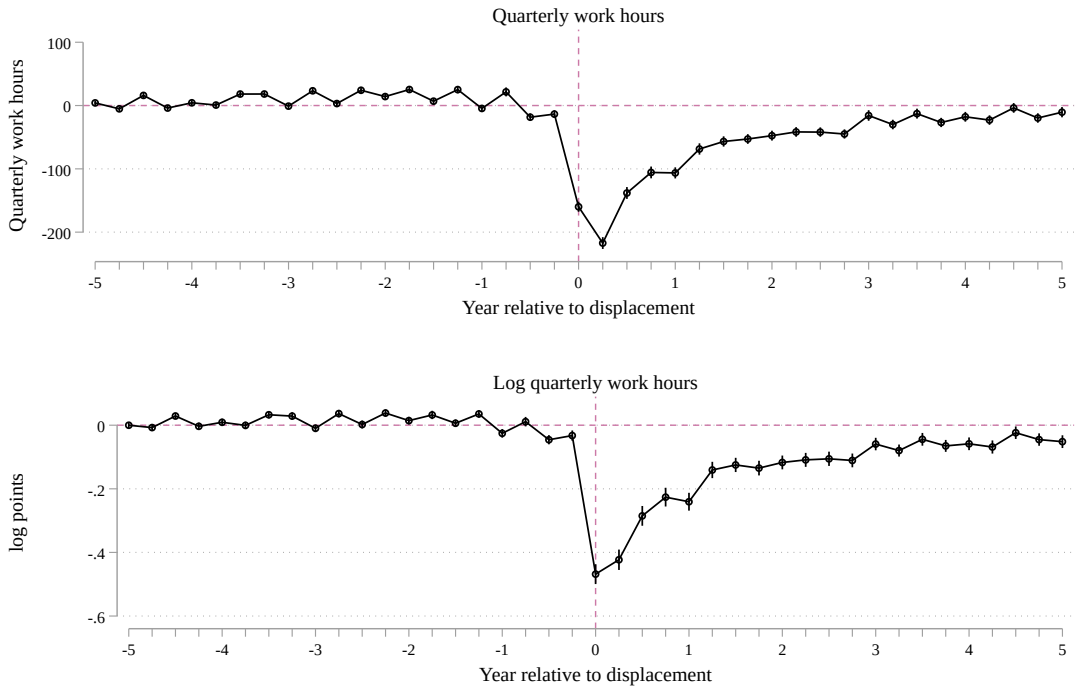
Notes: The top figure shows the quarterly earnings profiles (constant 2010 dollars) of workers displaced in Washington during the first quarter of 2009 (solid line) and the non-displaced comparison group (dashed line). The bottom figure shows the work hour profiles of the same two groups. Both earnings and hours are unconditional (that is, include observations of zero earnings and hours). The dashed vertical lines denote the quarter of separation.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.

Figure 2
Estimated earnings losses due to displacement, Washington, 2008–2010



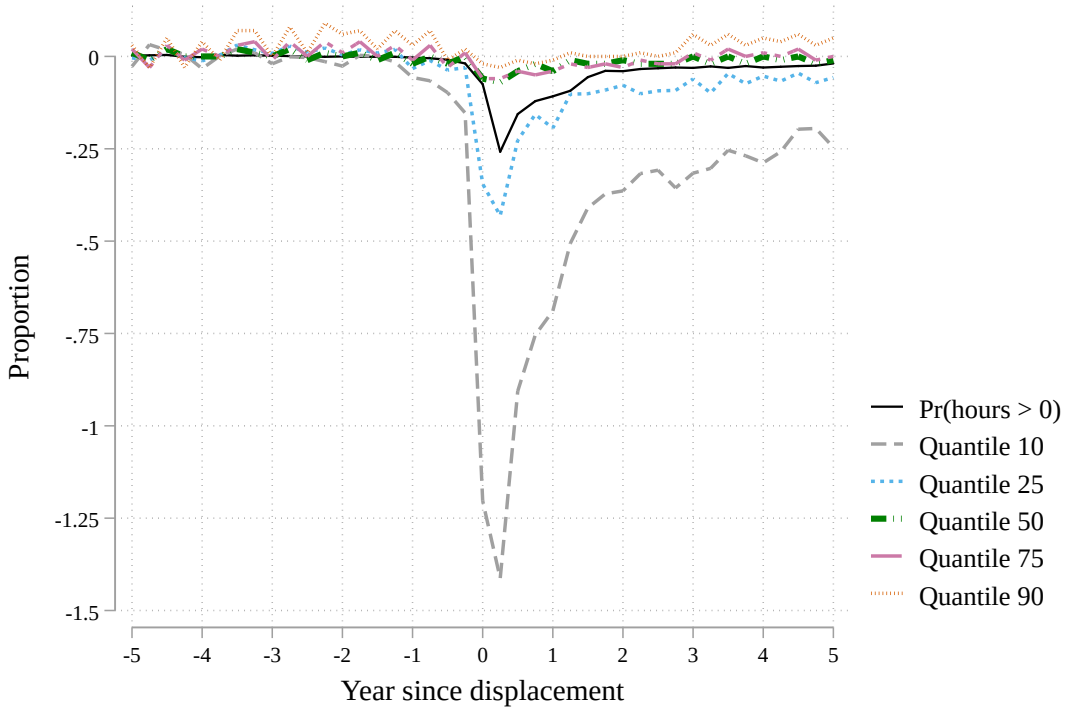
Notes: The top figure shows estimated δ_ks—quarterly unconditional earnings lost due to displacement (in constant 2010 $1,000s)—based on equation (1) with unconditional earnings from the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—logarithm of quarterly earnings lost due to displacement—based on equation (1) with the log of earnings from the primary employer as the dependent variable. Whiskers (which are very small) denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement. For the quarterly earnings computations, quarters of missing earnings are set to zero and included in the sample. For the log earnings computations, zero values are necessarily dropped, resulting in an unbalanced panel.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.

Figure 3
Estimated work hour losses due to displacement, Washington, 2008–2010



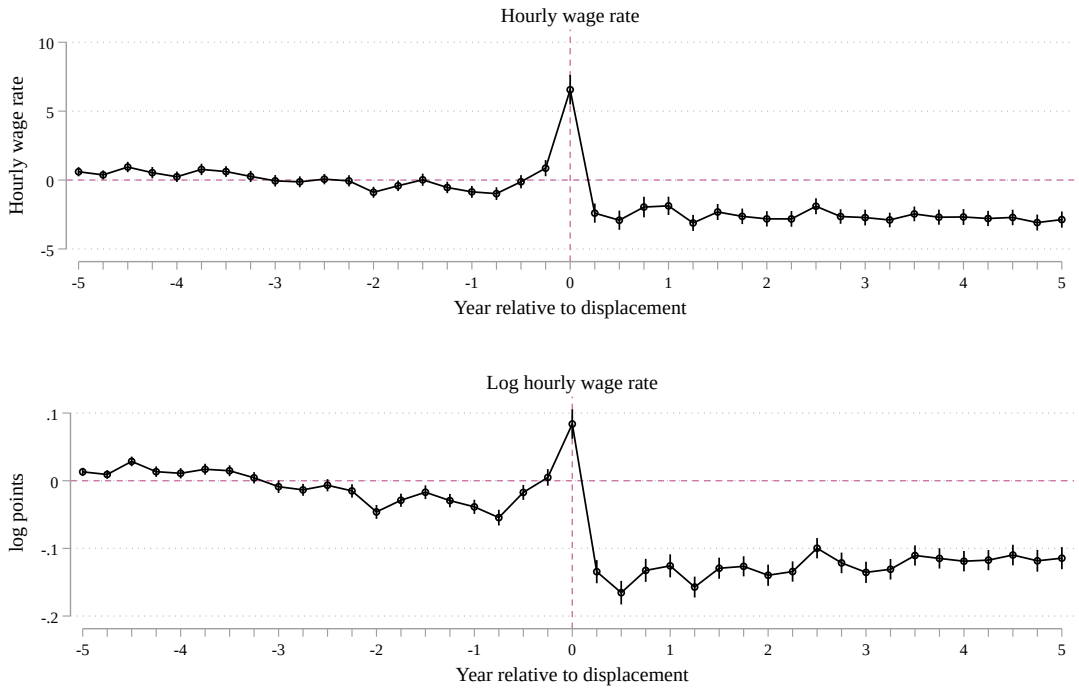
Notes: The top figure shows estimated δ_ks—quarterly unconditional hours lost due to displacement—based on equation (1) with unconditional hours at the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—logarithm of quarterly hours lost due to displacement—based on equation (1) with the log of hours at the primary employer as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement. For the quarterly hours computations, quarters of missing hours are set to zero and included in the sample. For the log hours computations, zero values are necessarily dropped, resulting in an unbalanced panel.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.

Figure 4
Estimated displacement effects on the probability of positive work hours and the distribution of quarterly work hours, Washington, 2008–2010



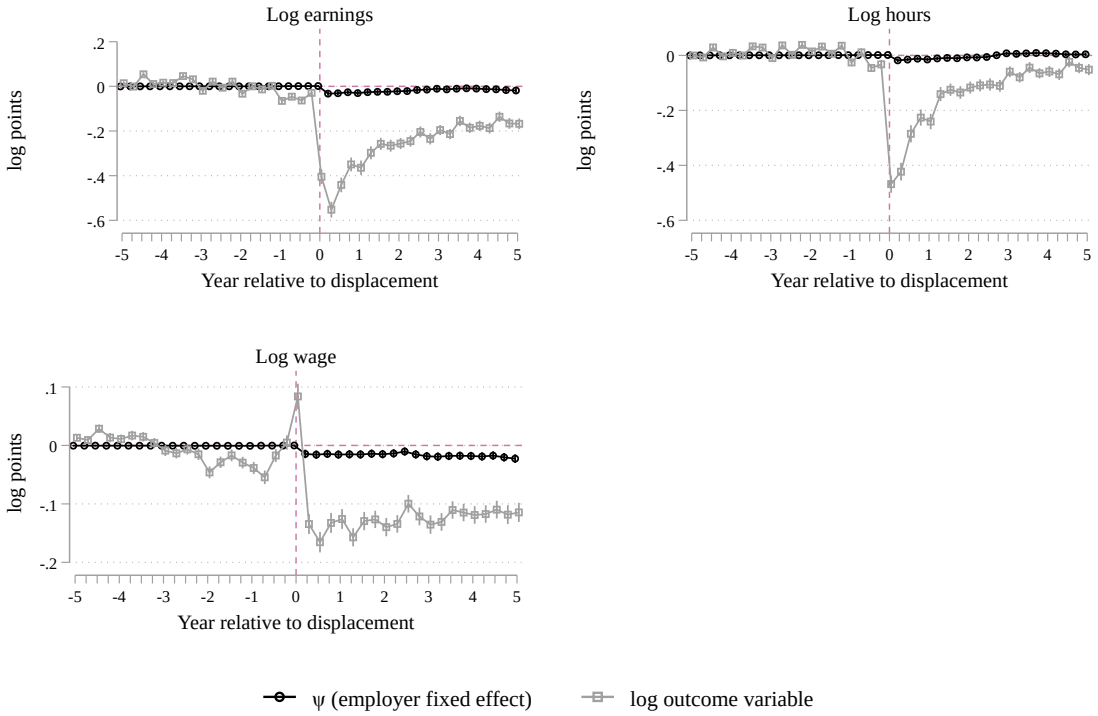
Notes: The line solid [Pr(hours > 0] shows estimated displacement effects on the probability of working a positive number of hours in a given quarter [δ_ks from a linear probability model specified as equation (1)]. Lines labeled "Quantile *n*" show estimated displacement effects (in proportional terms) at the 10th, 25th, 50th, 75th, and 90th, quantiles of the quarterly work hours distribution. The re-centered influence function approach of Firpo, Fortin, and Lemieux (2009) is used with a specification like equation (1). Proportional effects are obtained by dividing each estimated δ_k by the pre-displacement baseline hours of displaced workers at quantile *n*.
Source: Authors' calculations using Washington administrative wage and claims records. See Appendix Table A7 for the estimated δ_ks and baseline hours underlying the proportional changes shown in the figure, and section 4.2 of the text for further discussion.

Figure 5
Estimated hourly wage rate losses due to displacement, Washington, 2008–2010



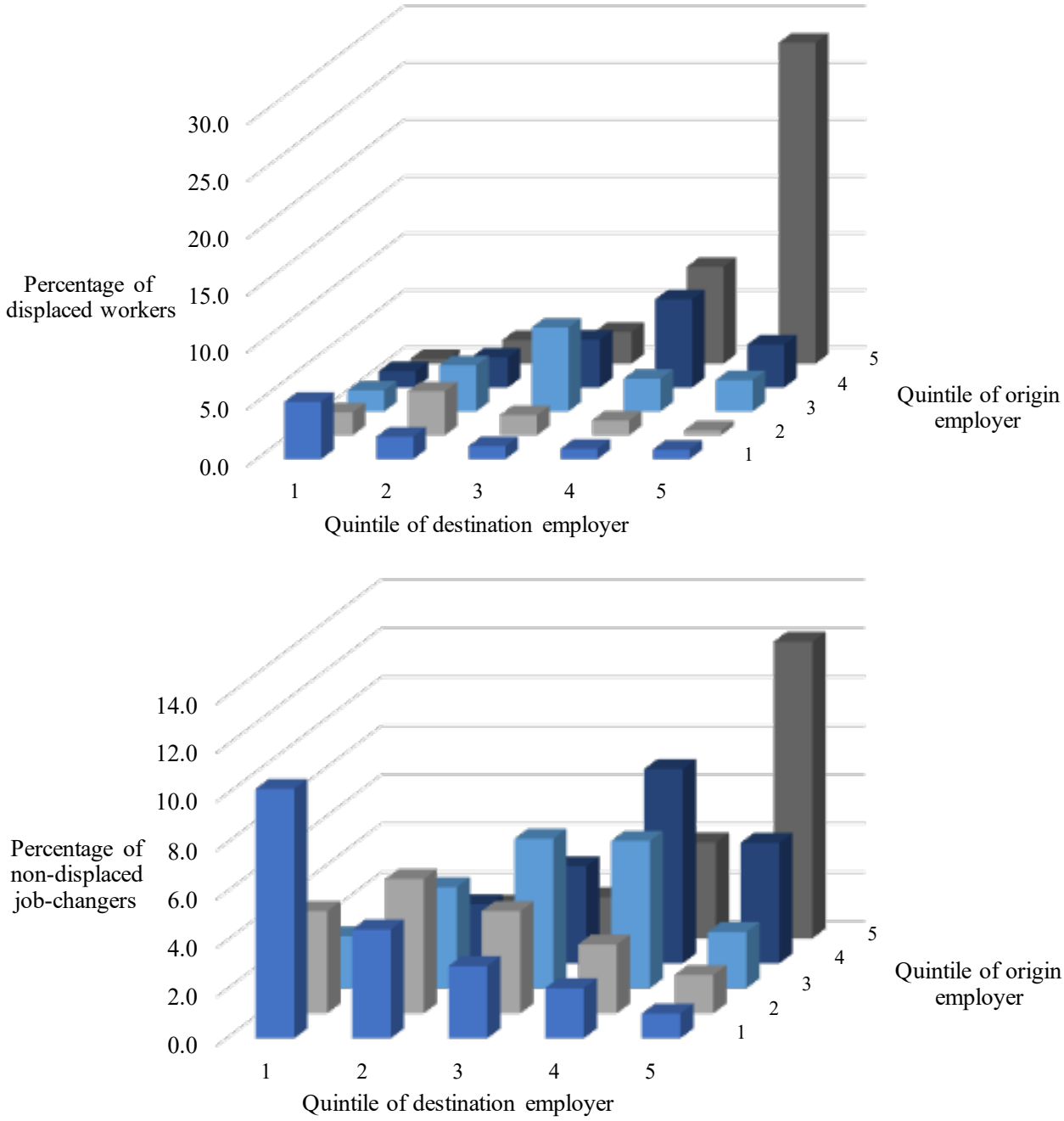
Notes: The figure shows estimated δ_ks—the reduction in the log hourly wage rate due to displacement—based on equation (1) with the log of hourly wage rate at the primary employer (constant 2010 dollars per hour) as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
For the hourly wage rate computations, quarters of missing earnings or hours are dropped from the sample, and similarly for the log hours computations, resulting in an unbalanced panel.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.

Figure 6
Estimated displacement losses due to lost employer fixed effects, Washington, 2008–2010



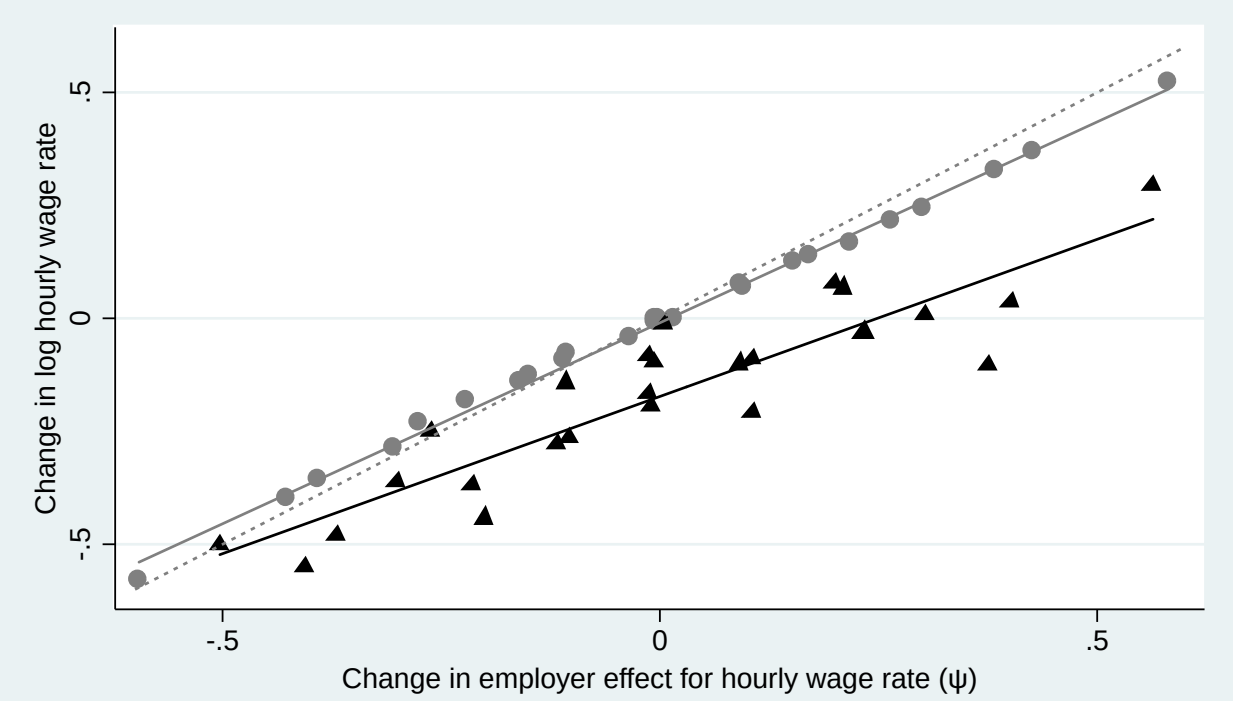
Notes: The figures show estimated displacement losses attributable to foregone employer fixed effects ($\widehat{\psi}$, shown as dark circles) compared with the full losses due to displacement (light squares, repeated from Figures 2, 3, and 5). Losses attributable to foregone employer fixed effects are estimates of δ_k from equation (3). For example, to obtain the estimates of earnings lost due to foregone employer premiums, equation (3) was estimated with the AKM employer fixed effect ($\widehat{\psi}$) for log earnings as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.2 and 5.1 of the text for details.

Figure 7
Inter-quintile employer fixed effect transitions of displaced workers (top) and non-displaced job changers (bottom), 2008–2010



Notes: The top histogram shows the percentage of displaced workers making each quintile-to-quintile transition.
Source: Data in Tables 4A and 4B.

Figure 8A
Changes in hourly wage rates and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Notes: The dashed line is a 45° line.
For displaced workers the fitted equation is:

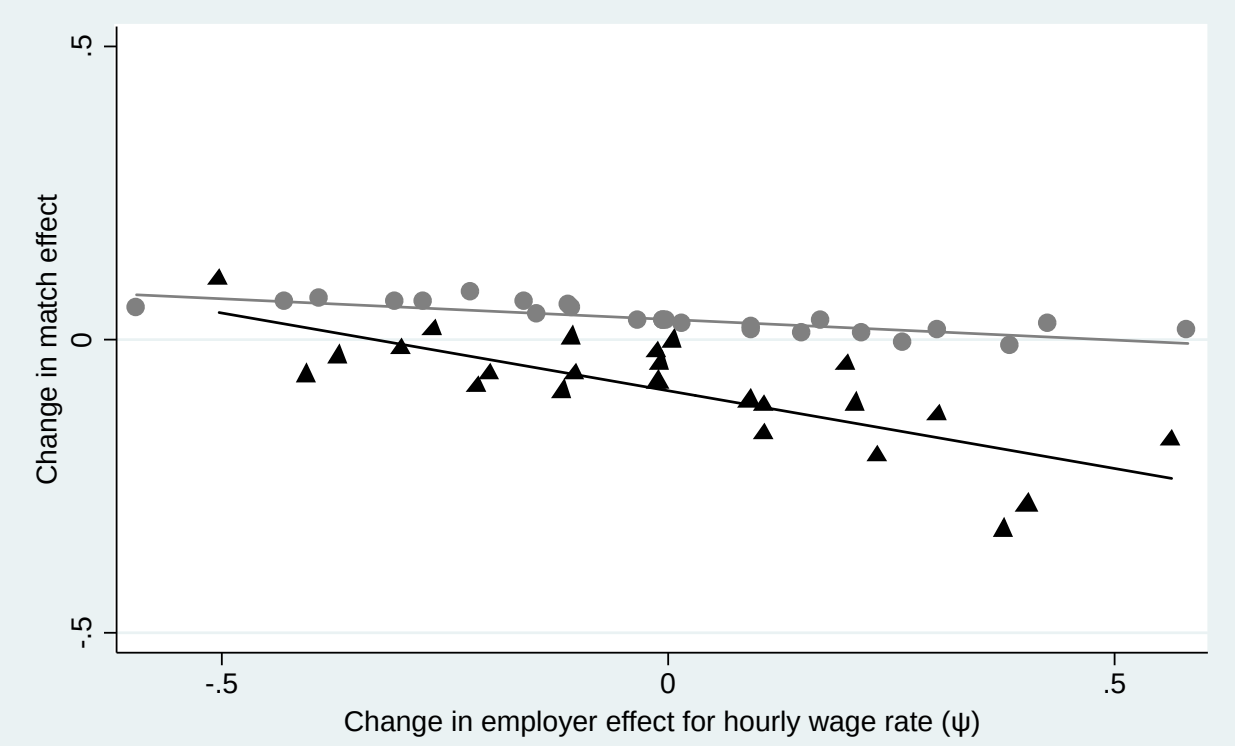
$$\Delta\ln(wage)^d = -0.173 + 0.696\Delta\psi^d \quad R^2 = 0.824,\ \text{RMSE} = 0.088,\ n = 25$$
$$(0.018)\ \ (0.067)$$

For non-displaced job changers the fitted equation is:

$$\Delta\ln(wage)^n = -0.010 + 0.889\Delta\psi^n \quad R^2 = 0.997,\ \text{RMSE} = 0.015,\ n = 25$$
$$(0.003)\ \ (0.011)$$

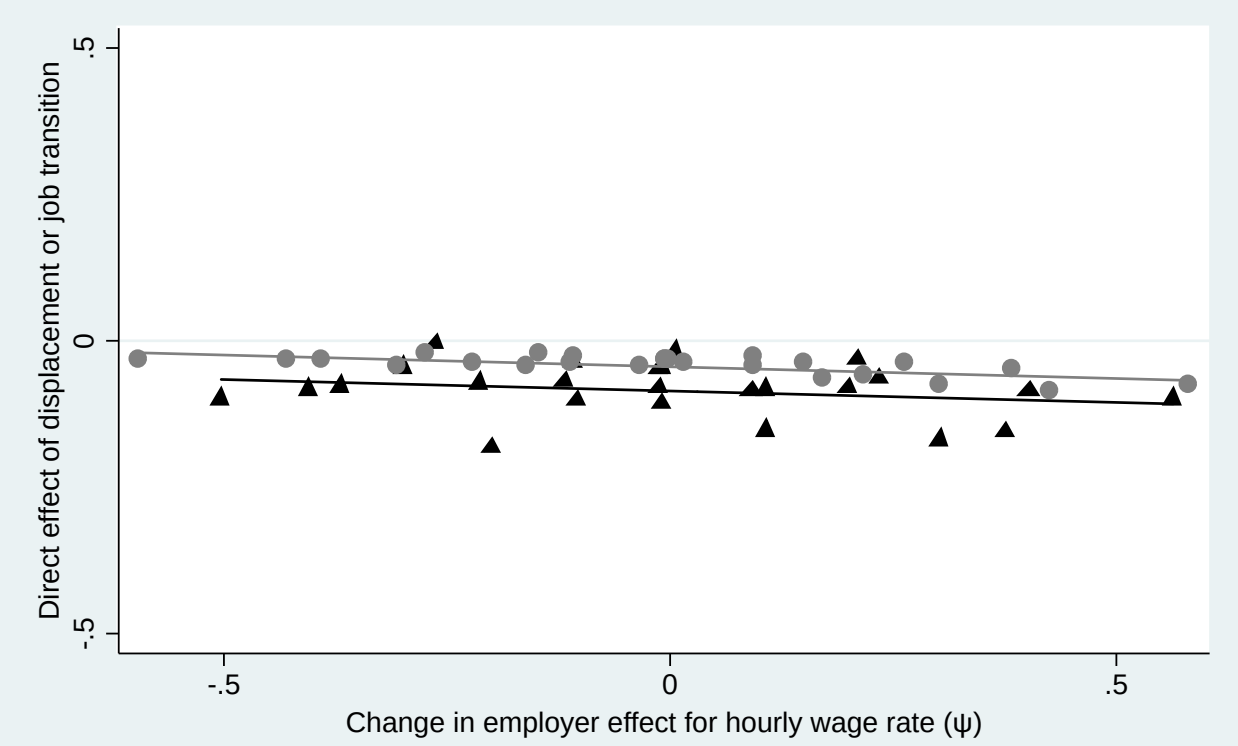
Source: Authors' calculations from the data in Tables 4A and 4B.

Figure 8B
Changes in match effects (μ for hourly wages) and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Notes:
For displaced workers the fitted equation is:
$\Delta\mu^d = -0.087 - 0.265\Delta\psi^d$ $R^2 = 0.594$, RMSE = 0.060, $n = 25$
(0.012) (0.047)
For non-displaced job changers the fitted equation is:
$\Delta\mu^n = 0.034 - 0.070\Delta\psi^n$ $R^2 = 0.672$, RMSE = 0.014, $n = 25$
(0.003) (0.010)
Source: Authors' calculations from the data in Tables 4A and 4B.

Figure 8C
Direct effects of displacement or job transition (d for hourly wages) and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Notes:
For displaced workers the fitted equation is:

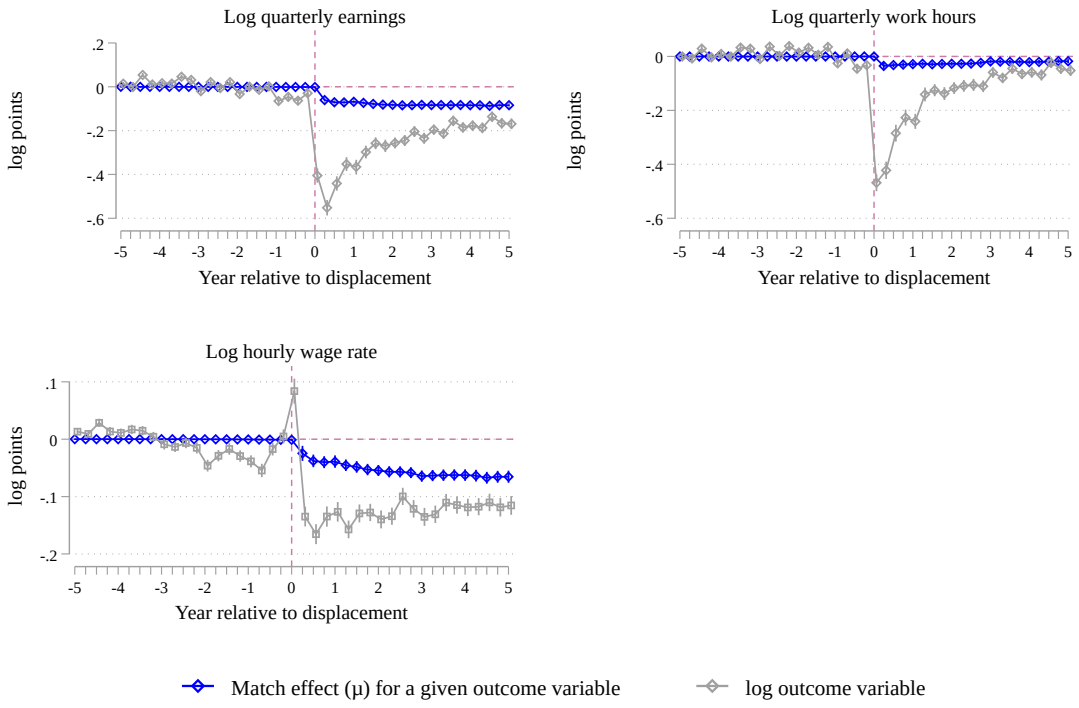
$\Delta d^d = -0.086 - 0.039\Delta\psi^d$ $R^2 = 0.054$, RMSE = 0.045, $n = 25$
(0.009) (0.033)

For non-displaced job changers the fitted equation is:

$\Delta d^n = -0.044 - 0.040\Delta\psi^n$ $R^2 = 0.477$, RMSE = 0.012, $n = 25$
(0.002) (0.009)

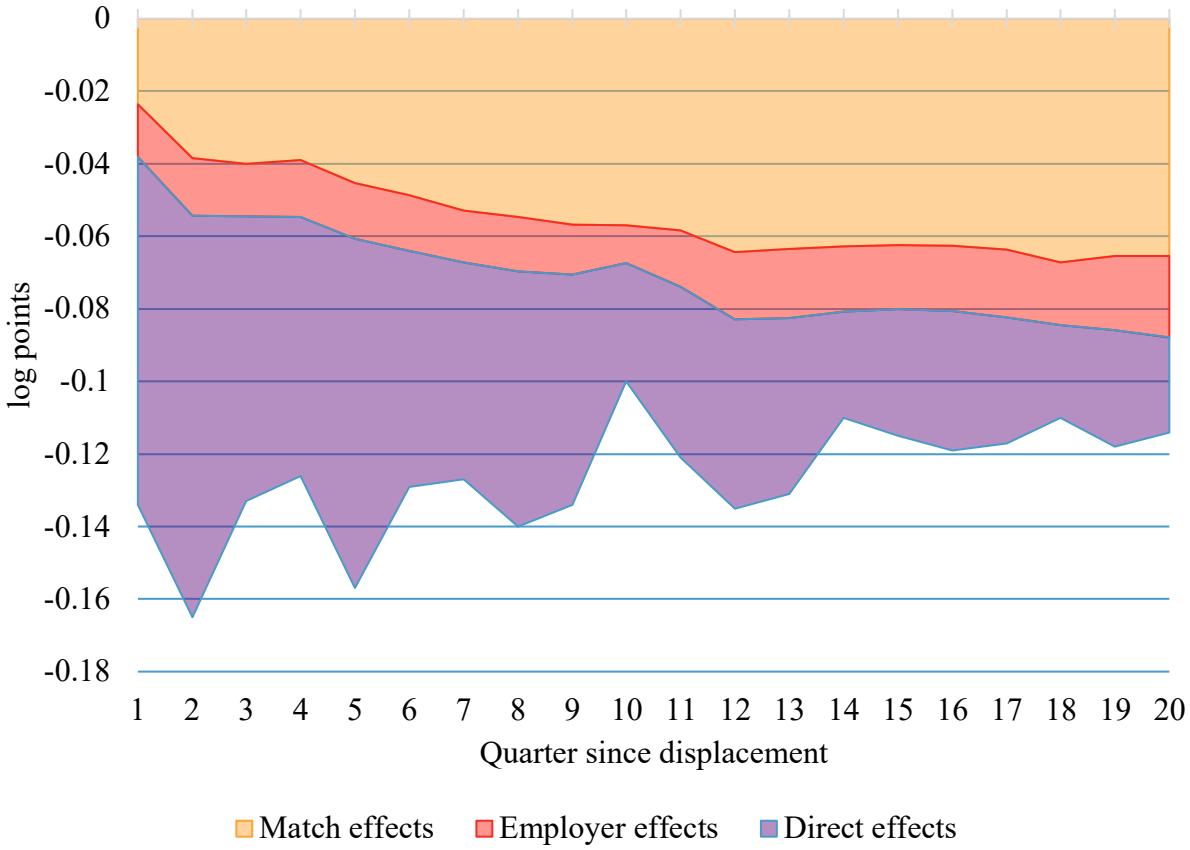
Source: Authors' calculations from the data in Tables 4A and 4B.

Figure 9
Estimated displacement losses attributable to lost worker-employer match effects ($\hat{\mu}$)



Notes: The figures show estimated displacement losses attributable to lost worker-employer match effects ($\hat{\mu}$, shown as diamonds), estimated by Woodcock's (2015) method, compared with the full losses due to displacement (circles, repeated from Figures 2, 3, and 5). Losses attributable to foregone match effects are estimates of δ_k from an equation like equation (3) with ($\hat{\mu}_{ij}$) as the dependent variable. For example, to obtain the estimates of earnings lost due to lost match effects, equation (3) was estimated with the Woodcock match effects ($\hat{\mu}$) for log earnings as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.3 and 5.4 of the text for details.

Figure 10
Decomposition of hourly wage rate reductions after displacement



Notes: The figure illustrates the decomposition of the log hourly wage rate reductions following displacement into portions attributable to lost worker-employer match quality [estimated using Woodcock's (2015) method], lost employer fixed effects, and the direct displacement effects. See sections 5.4 and 6 for further discussion.
Source: Authors' calculations based on data in Figures 5, 6, and 9.

Sources of Displaced Workers' Long-Term Earnings Losses: Appendices

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May 24, 2019

Appendix A
Alternative Estimates, Additional Analyses, and Other Supporting Material

Appendixes A.1, A.3, A.4, A.5, A.6, and A.7 describe sensitivity tests of the estimates reported in the main text. Appendix Table A1 gives a tabular summary of these results.

Appendix A.2 compares the unemployment rates in Washington, Connecticut, Pennsylvania, and the United States for selected time periods relevant to displaced worker studies using administrative data.

Appendix A.8 describes estimates using the specification and sampling choices used by Schmieder, von Wachter, and Heining (2018).

Appendix A.9 presents inter-quintile employer fixed effects transitions, changes in earnings and hours worked, and employer fixed effect changes for earnings and hours worked.

Appendix A.10 compares alternative estimates of displacement losses due to lost match effects.

Appendix A.11 is made up of four tables supporting Figures 2, 3, 5, and 6 in the main text.

Appendix Table A1
Summary of estimated quarterly losses due to displacement

	Earnings		Hours		Hourly wage rate	
	Q1	Q17–Q20	Q1	Q17–Q20	Q1	Q17–Q20
1. Displaced workers, UI claimant sample, full losses (sections 4.1 and 4.2)						
levels	–$6,531	–$2,026	–217	–14.2	–2.40	–2.86
	(–48.9%)	(–15.2%)	(–41.8%)	(–2.74%)	(–4.14%)	(–4.93%)
log points	–0.552	–0.164	–0.423	–0.047	–0.134	–0.115
2. Displaced workers, UI claimant sample, changes due to employer fixed effects (section 5.1)						
log points	–0.033	–0.015	–0.018	0.0046	–0.015	–0.020
3. Displaced workers, UI claimants with shorter job tenure (3–4 years), full losses (Appendix A.1)						
log points	–0.641	–0.153	–0.558	–0.139	–0.063	–0.013
4. Displaced workers, UI claimant sample including less strongly attached, full losses (Appendix A.3)						
log points	–0.531	–0.248	–0.425	–0.116	–0.115	–0.134
5. Displaced workers, UI claimant sample alternative comparison group, full losses (Appendix A.4)						
log points	–0.477	–0.080	–0.376	+0.002	–0.109	–0.081
6. Displaced workers, broadened sample, full losses (Appendix A.5)						
log points	–0.490	–0.232	–0.380	–0.090	–0.145	–0.105
7. Displaced workers, UI claimant sample, excluding NAICS industries 51–56, full losses (Appendix A.6)						
log points	–0.645	–0.166	–0.461	–0.0758	–0.185	–0.0908
8. Displaced workers, UI claimant sample, full losses from random trends model (Appendix A.7)						
log points	–0.542	–0.147	–0.409	–0.0319	–0.135	–0.011
9. Displaced workers, UI claimant sample, full losses (Schmieder, von Wachter, and Heining 2018 setup), (Appendix A.8)						
log points	–0.516	–0.0760	–0.416	–0.0380	–0.103	–0.0380
10. Displaced workers, UI claimant sample, changes due to match effects (section 5.4 and Appendix A.10)						
log points	–0.0624	–0.0848	–0.0379	–0.0188	–0.0236	–0.0654
11. Displaced workers, UI claimant sample, changes due to match effects (unadjusted) (Appendix A.10)						
log points	–0.0765	–0.0962	–0.0330	–0.0157	–0.0431	–0.0804

Note: Each entry gives the estimated displacement effect on the indicated outcome in either quarter 1 (Q1) or the average of quarters 17, 18, 19, and 20 (Q17–Q20) following displacement. For levels, implied percentage changes relative to the non-displaced comparison group are shown in parentheses. (For example, the estimated effect of displacement on average earnings in quarters 17–20 after displacement is –$2,026, which is 15.2% less than the earnings of the non-displaced comparison group.)

Appendix A.1
Estimated losses of workers with relatively short job tenure

An implication of the specific human capital hypothesis is that longer pre-displacement job tenure will be associated with larger earnings losses (e.g., Topel 1990; Neal 1995; Carrington and Fallick 2017). Farber (1993) found that, on average, each additional year of pre-displacement job tenure was associated with an additional one percent drop in post-displacement earnings. In contrast, in a study using administrative data, von Wachter, Song, and Manchester (2009) found insubstantial differences between the earnings losses of workers with three years of tenure and workers with six or more years of tenure.

This appendix examines and compares the earnings, hours, and wage rate losses of workers with 6 or more years of pre-displacement job tenure (the main UI claimant sample) to the losses of workers with only 3–4 years of pre-displacement job tenure. To do this, we first select displaced workers with 3–4 years of tenure according to the criteria described in section 2.1 (other than the six-year tenure requirement). We then estimate equation (1) using as the comparison group non-displaced workers with 6 or more years of tenure, so that comparisons between short- and long-tenure displaced workers are made with respect to the same comparison group. This is a descriptive exercise, not an attempt to estimate the effect of job tenure on the outcomes of displaced workers.

Appendix Figure A1 shows the estimated profiles of earnings, work hours, and wage rates (in logs), and the estimated time path of the quarterly employment probability—see also row 3 of Appendix Table A1. The earnings losses and employment probabilities of displaced workers with 3–4 years of tenure are similar to those with 6 or more years of tenure, consistent with the findings in von Wachter, Song, and Manchester (2009). However, the patterns of hours losses and wage rate reductions differ sharply between the two groups. The hours losses of short-

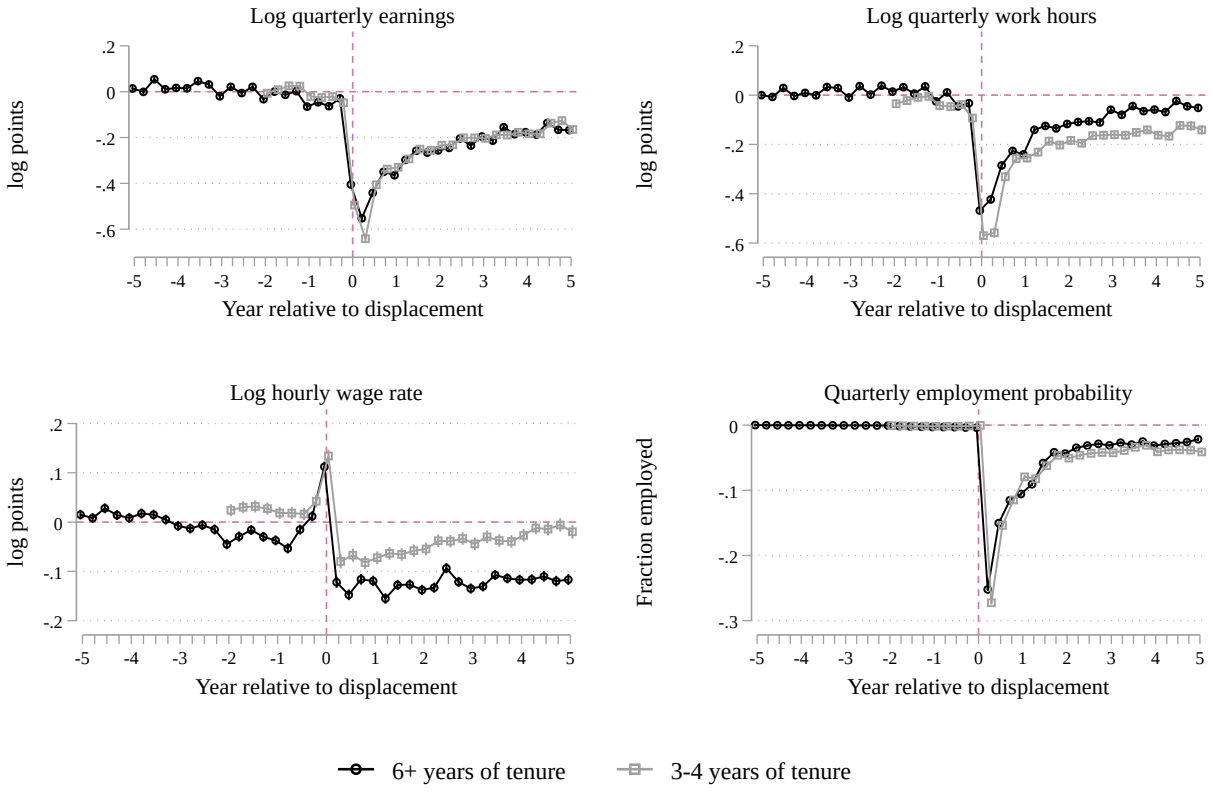
tenure displaced workers are larger than the hours losses of long-tenure displaced workers, but their wage rates losses are less, and those losses are minimal four years after displacement. This contrasts with the wage rate losses of long-tenure displaced workers, which plummet at the time of displacement and never even partially recover.

A possible interpretation of these estimates is that the reduced work hours of long-tenure displaced workers represent a labor supply response to their reduced wage rates, whereas the substantially reduced hours of short-tenure displaced workers, along with wage rates similar to those faced before displacement, suggests demand constraints faced by these workers. The implication is that short- and long-tenure displaced workers differ in ways that should not be attributed to previous job tenure alone.[1]

Appendix Figure A2 shows that, as was the case for displaced workers who had six or more years of job tenure, employer fixed effects account for a negligible portion of the reduced earnings, work hours, and wage rates of displaced workers with relatively short tenure.

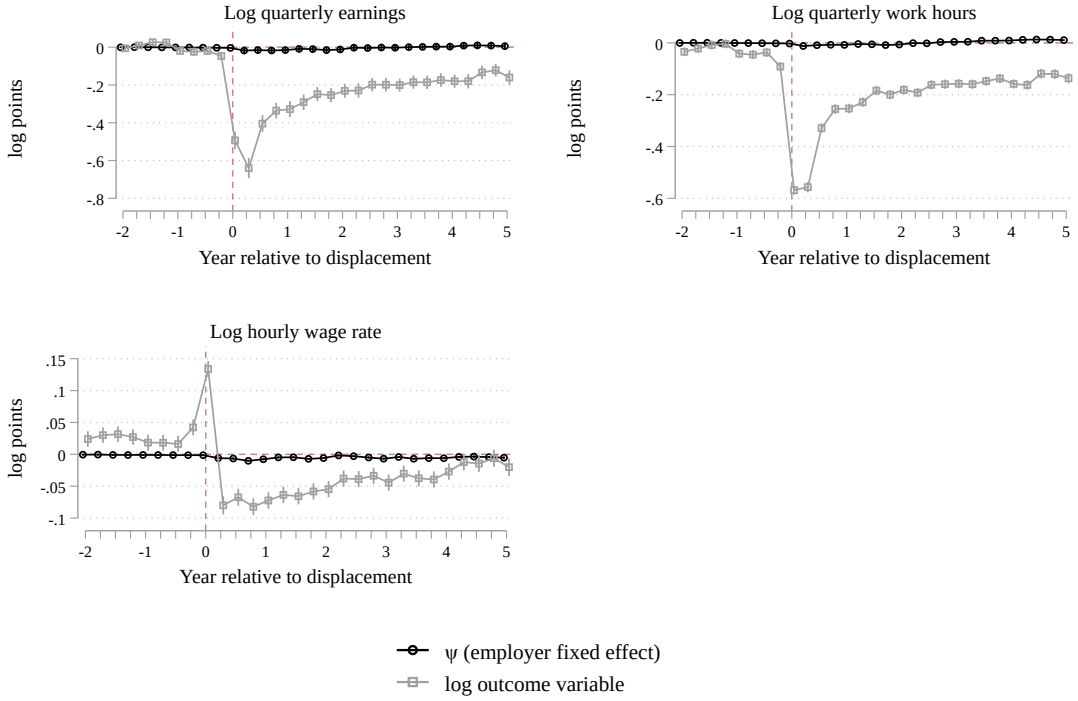
[1] We have also examined losses due to displacement separately for workers younger than age 40 in the quarter of displacement, and for workers age 40 and older in the quarter of displacement. (To construct the non-displaced comparison groups, we use age in 2007:IV.) The estimated long-term earnings, hours, and wage-rate losses of the younger and older workers are quite similar, which is surprising because older workers have on average longer job tenure. However, the reemployment rates of older workers in the first two years after displacement are lower than those of younger workers, consistent with Farber's (2017) findings.

Appendix Figure A1
Estimated displacement effects for workers with relatively short job tenure



Notes: The figures show estimated displacement effects for workers with 3–4 years of job tenure at the time of displacement (squares), and 6 or more years of job tenure at the time of displacement (circles, repeated from Figures 2, 3, 5 in the main text for the first three panels). The reference time period for workers displaced with 3–4 years of tenure (and their comparison group) is 3 years before displacement. Each figure shows the profile of displacement effects for an outcome—quarterly log earnings, log hours, log wage rate (all from the primary employer), or the probability of employment (positive earnings or hours)—based on estimates of δ_k in equation (1). Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.

Appendix Figure A2
Estimated displacement losses due to foregone employer fixed effects for workers with relatively short job tenure



Notes: The figures show estimated displacement losses attributable to foregone employer fixed effects (circles) compared with the full losses due to displacement for workers with 3–4 years of job tenure at the time of displacement (squares, repeated from Appendix Figure A1). Losses attributable to foregone employer fixed effects are estimates of δ_k from equation (3). For example, to obtain the estimates of earnings lost due to foregone employer premiums, equation (3) was estimated with the AKM employer fixed effect ($\widehat{\psi}$) for log earnings as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records.

Appendix A.2
Unemployment rates in Washington, Connecticut, Pennsylvania, and the United States, selected time periods

This appendix compares the United States national unemployment rate with that in Washington in 2002–2014 (Appendix Figure A3), Connecticut in 1993–2004 (Appendix Figure A4), and Pennsylvania in 1974–1986 (Appendix Figure A5)—the states and years studied by Lachowska, Mas, and Woodbury (2018), Couch and Placzek (2010), and Jacobson, LaLonde and Sullivan (1993a, b).

Appendix Figure A3 shows that the unemployment rate in Washington improved relative to the US national average in the recovery leading up to the 2008–2010 recession, then fell somewhat below the national average during the recession itself. However, the Washington unemployment rate peaked above the national rate and remained above the national rate until mid 2012. Overall, the Great Recession in Washington appears to have reflected the national experience with a lag of a few months.

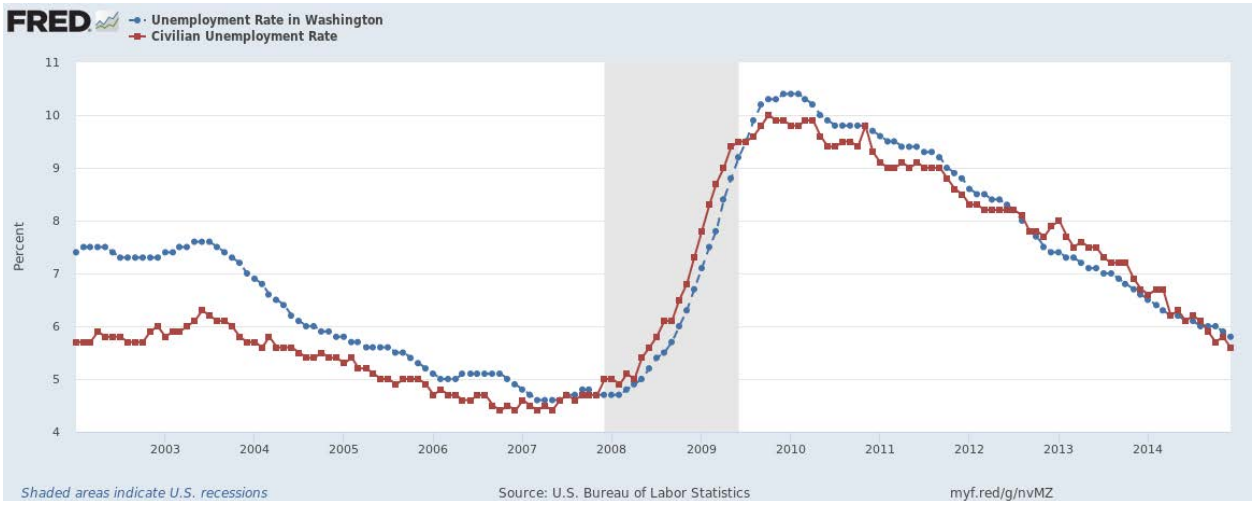
In contrast, the 2001 recession in Connecticut appears to have followed a different pattern than the national downturn—see Appendix Figure A4. Connecticut's unemployment rate was 1–2 percentage points lower than the national average throughout the recession, then increased relative to the national average, peaking about 1 percentage point below the national average in 2003. Connecticut, then, started the recession in a substantially better position than the national labor market, then became more like the national labor market over the next two years.

Appendix Figure A5 shows that the double-dip recession of the early 1980s was especially severe in Pennsylvania, even compared with the national experience. Pennsylvania's unemployment rate started the 1980 recession nearly one percentage point above the national

average, then increased by nearly an additional point relative to the national average—which itself increased by four percentage points.

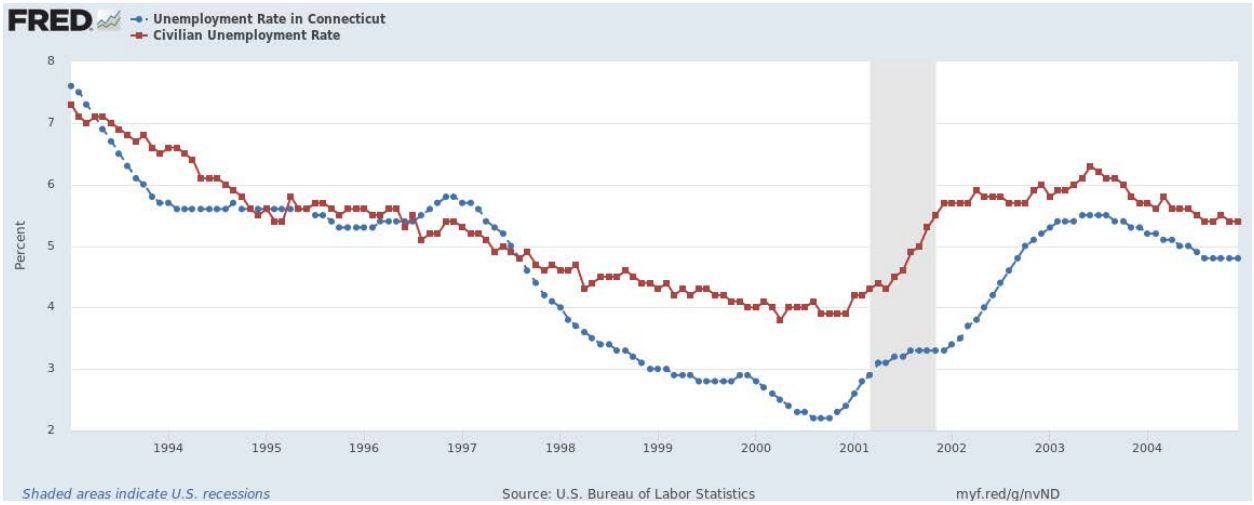
In summary, of the three recessions studied by us, CP, and JLS, the Washington experience during the Great Recession appears to have reflected the national experience most closely, and the Pennsylvania experience during the double-dip recession of the early 1980s was the most severe both absolutely and relative to the national average.

Appendix Figure A3
Civilian monthly unemployment rate, Washington and United States, 2002–2014



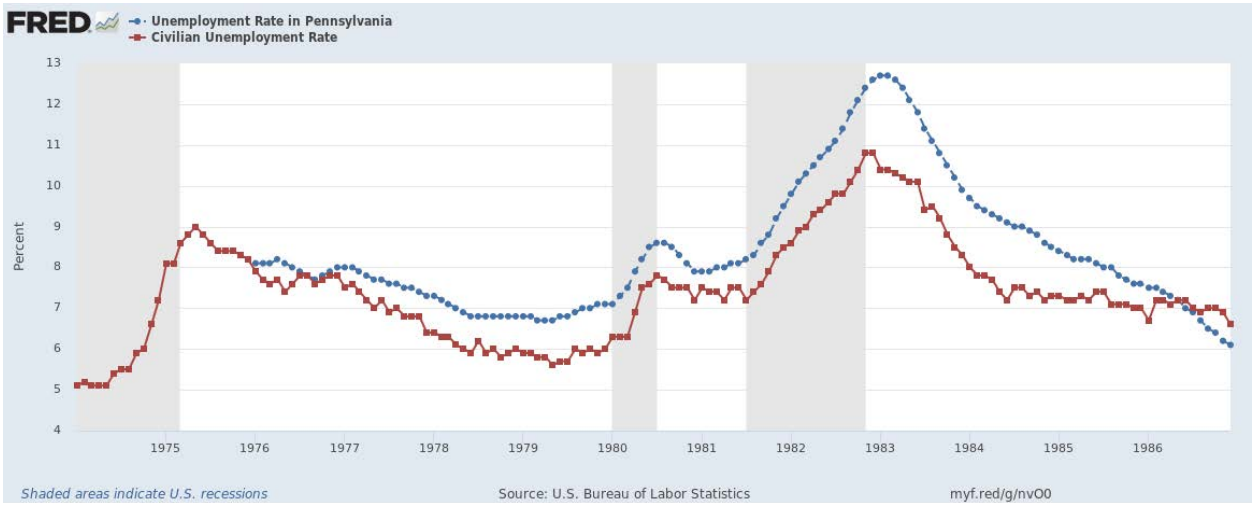
Source: Federal Reserve Bank of St. Louis Economic Data (FRED), based on data from U.S. Bureau of Labor Statistics.

Appendix Figure A4
Civilian monthly unemployment rate, Connecticut and United States, 1993–2004



Source: Federal Reserve Bank of St. Louis Economic Data (FRED), based on data from U.S. Bureau of Labor Statistics.

Appendix Figure A5
Civilian monthly unemployment rates, Pennsylvania and United States, 1974–1986



Note: The unemployment rate in Pennsylvania is only available from 1976.
Source: Federal Reserve Bank of St. Louis Economic Data (FRED), based on data from U.S. Bureau of Labor Statistics.

Appendix A.3
Estimated losses of displaced workers including those less strongly attached to the labor force

The estimates in Figures 2, 3, and 5 of the main text are based on the UI claimant sample, which is restricted to displaced workers who were strongly attached to the labor force; that is, were employed in at least one quarter per calendar year in each year following displacement.

Relaxing the restriction of strong attachment, so that a displaced worker need not have positive earnings in at least one quarter per year after being displaced, results in an additional 1,509 displaced workers. These 1,509 displaced workers are assigned zero earnings and hours in quarters when their earnings and hours are missing and are then added to the UI claimant sample, yielding a total sample of 4,199. (Necessarily, zero values are dropped from the analysis when using outcomes in logarithmic form, resulting in an unbalanced panel.) To be clear, these 1,509 displaced workers claimed UI at some time during 2002–2014, so we observe their demographic characteristics.

Appendix Table A2 displays the descriptive statistics of both the 2,690 displaced workers in the UI claimant sample and the 1,509 additional displaced workers who were less strongly attached to the labor force. On average, the 1,509 less strongly attached displaced workers had higher pre-displacement earnings and wage rates than the UI claimant sample, and they were more likely to have a bachelor's or advanced degree. Of these 1,509 displaced workers, only 26 were **never** observed with positive earnings after being displaced. Compared with the UI claimant sample workers, these 26 workers also had higher pre-displacement earnings and wage rates, and again had higher educational attainment.[2]

[2] That only 26 displaced workers never had any positive earnings after displacement may be surprising; however, these workers had at least six years of job tenure before displacement and were no older than 50 at the time of displacement, so they were strongly attached to the labor force. JLS (1993b, p 16) also find that labor force withdrawal is rare among long-tenure prime-age workers.

Appendix Figure A6 plots the estimated time paths of lost log earnings, log hours, and log wage rates for the augmented sample, consisting of the main UI claimant sample plus the sample of less attached displaced workers (squares), along with the time paths of earnings, work hours, and wage rates for the main displaced worker sample (circles, repeated from Figures 2, 3, and 5 in the main text)—see also row 4 of Appendix Table A1. The comparison group used to obtain the estimated losses of the augmented sample is the same 13,290 continuously employed workers who were used to obtain the main estimates.

Estimates based on the augmented sample differ in two main ways from those based on the main UI claimant sample. First, five years after displacement, work hours of the augmented sample were 11.6 log points lower than those of the comparison group, compared with 4.7 log points lower in the main UI claimant sample (compare rows 1 and 4 of Appendix Table A1). Earnings losses were also larger by nearly 25 log points in the augmented sample, compared with 16.4 log points lower in the baseline sample.[3] Second, relative to the comparison group, the probability of employment (positive earnings or hours in a quarter) five years after displacement was 18 percent less for the augmented sample, compared with 3 percent less for the main UI claimant sample.

Given the above differences, it is somewhat surprising that the average hourly wage rate losses are quite similar for the main UI claimant sample and the augmented sample—11.5 log points for the former, 13.4 log points for the latter.

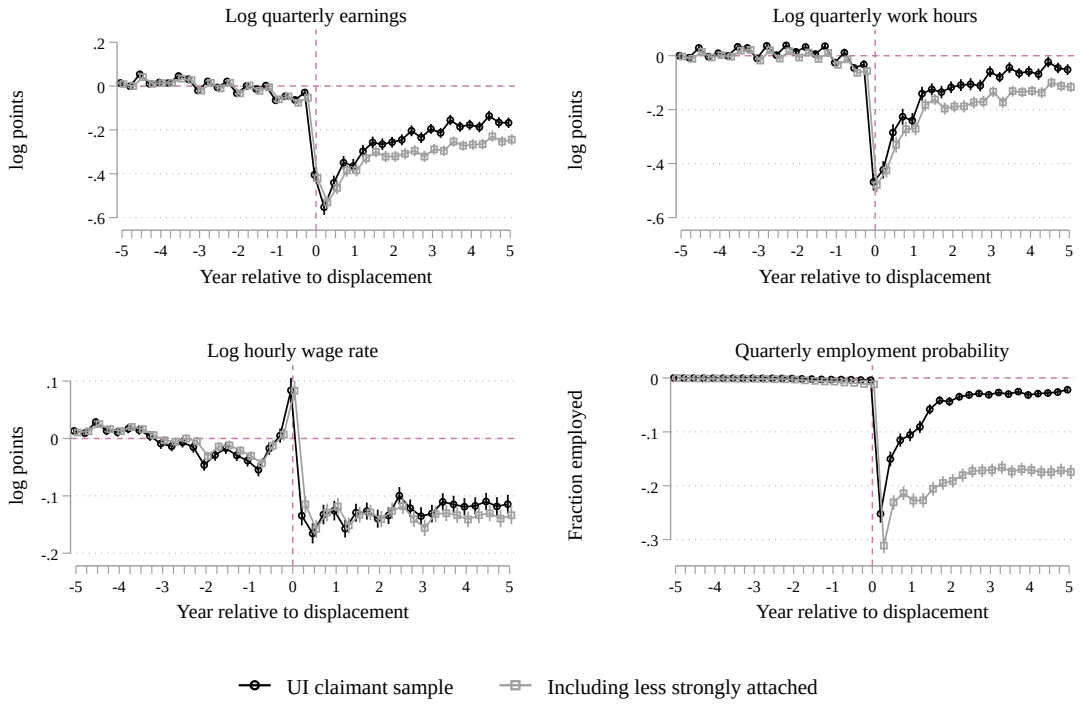
[3] When Couch and Placzek (2010, p. 579) relax the labor force attachment restriction, they find earnings losses that are greater by 15–18 percentage points, substantially larger than the 9 log-point increase we estimate.

Appendix Table A2
Sample descriptive statistics for UI claimant sample (2,690 workers), additional displaced workers who did not have positive earnings once per calendar year after being displaced (1,509 workers), and displaced workers who never had positive post-displacement earnings (26 workers)

	(1)	(2)	(3)
		Displaced workers	
	UI claimant sample	Workers not required to have earnings > 0 at least one quarter per year post-displacement	Workers with no earnings > 0 post-displacement
Quarterly average earnings, hours, and wage rates, 2002–2005			
Earnings (2010 dollars)	13,349	14,575	14,861
	(6,466)	(8,063)	(9,499)
Paid work hours	519	511	506
	(82)	(82)	(66)
Hourly wage rate (2010 dollars/hour)	58.00	69.16	63.52
	(43.12)	(47.21)	(47.63)
Worker characteristics, 2007:IV			
Female (proportion)	0.286	0.372	0.269
Race (proportions)			
White, not Hispanic	0.779	0.767	0.769
Black, not Hispanic	0.030	0.033	0.038
Hispanic	0.073	0.071	0.077
Asian/Pacific Islander	0.071	0.074	0.038
American Indian or Alaskan Native	0.013	0.016	0.038
Missing, unknown, or not available	0.035	0.040	0.038
Schooling (proportions)			
less than high school	0.080	0.060	0.154
GED	0.031	0.029	0.000
high school graduate	0.465	0.390	0.231
some college	0.149	0.154	0.115
associate's degree	0.124	0.130	0.154
bachelor's degree	0.125	0.162	0.269
master's/PhD	0.026	0.047	0.077
Age (years)	39.45	40.42	40.58
	(6.46)	(6.36)	(6.09)
Employer characteristics in 2007:IV			
Employer size (number of workers)	2,042	1,974	1,244
	(2,578)	(2,440)	(1,800)
NAICS Industry (proportions)			
11 agriculture, forestry, fishing	0.016	0.009	0.000
21–23 mining, utilities, construction	0.088	0.068	0.039
31–33 manufacturing	0.277	0.276	0.423
42–49 trade, transportation	0.160	0.145	0.192
51–56 information, finance, prof. services	0.377	0.427	0.269
61–62 educational and health care services	0.013	0.013	0.000
71–72 arts, recreation, hospitality services	0.055	0.052	0.077
81 other services	0.007	0.060	0.000
92–99 public administration and unclassified	0.007	0.053	0.000
Number of employers (pre- and post-displacement)	3,493	1,979	39
Number of workers	2,690	1,509	26

Notes: Standard deviations in parentheses. The 26 workers who were never observed with positive post-displacement earnings (column 3) are included with the 1,509 workers in column (2).
Source: Authors' tabulations of Washington administrative wage and claims records. See section 2.1 for details of the UI claimant sample construction.

Appendix Figure A6
Estimated displacement effects, including workers less strongly attached to the labor force



Notes: The figures show estimated displacement effects for the UI claimant sample (circles, repeated from Figures 2, 3, and 5 of the main text, N = 2,690) and for the UI claimant sample augmented by displaced workers not required to be observed with positive earnings or hours after being displaced (squares, N = 4,199, the sum of the UI claimant sample and the displaced workers less strongly attached to the labor force). The whiskers denote 95–percent confidence intervals clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.

Appendix A.4
Estimates using an alternative comparison group

The comparison group used by JLS included only workers continuously employed with their primary employer throughout the observation period (in our case, 2002–2014). As Krolikowski (2018) points, this could lead to an overstatement of displaced workers' losses. Accordingly, we estimate equation (1) using a comparison group of long-tenure workers (employed by the same primary employer during 2002–2007) who continued with the same employer (were not displaced) during 2008–2010, but who may have changed employers or separated from their primary employer sometime after 2010. We interpret the estimates obtained using this alternative comparison group as a lower bound of the effects of displacement.

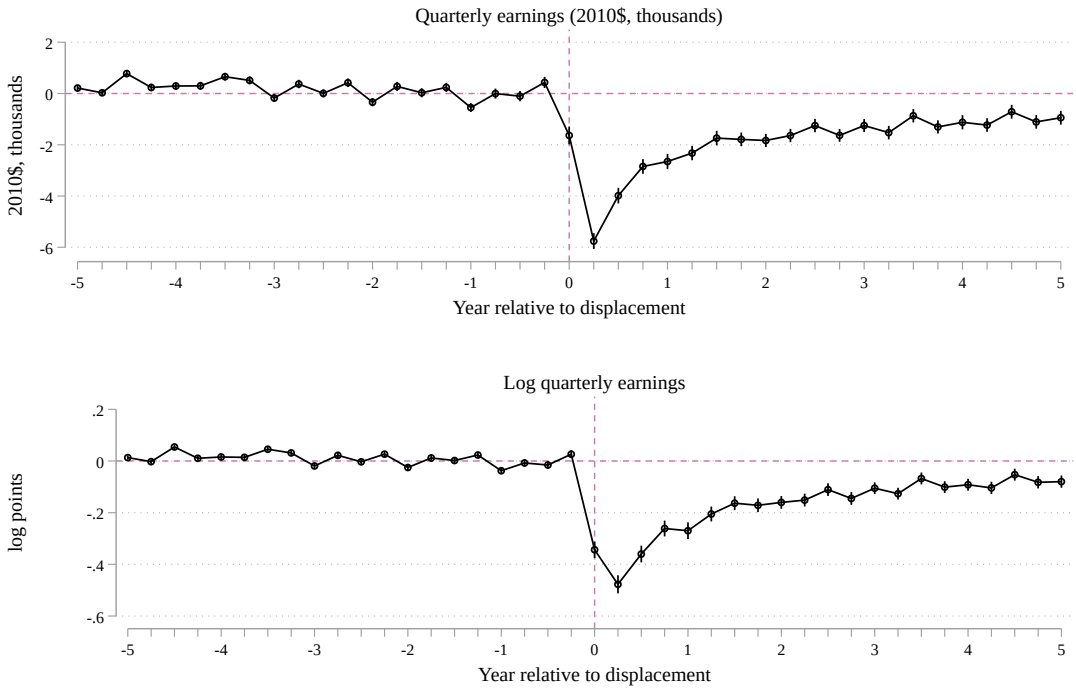
Appendix Figures A7–A9 show the results of estimating equation (1) for earnings, hours, and hourly wage rates, using this alternative comparison group—see also row 5 of Appendix Table A1. The short-term losses are similar to those in Figures 2, 3, and 5: In the quarter after displacement, earnings dropped by 48 log points (compared with 55 log point using the continuously employed comparison group), hours dropped by 38 log points (compared with 42 log points using the continuously employed comparison group), and wage rates were lower by 11 log points (compared with about 13 log points using the continuously employed comparison group).

Long-term earnings and hours losses estimated using the alternative comparison group are substantially less than those estimated using the continuously employed comparison group: After five years, earnings were lower than the alternative comparison group's by about 8 log points (compared with 16 log points using the continuously employed comparison group), and hours recovered completely (compared with a 5 log-point loss). However, the difference between hourly wage rate losses using the different comparison groups is less striking: they were lower

by 8 log points using the alternatively comparison group (compared with 11.5 log points using the continuously employed group).

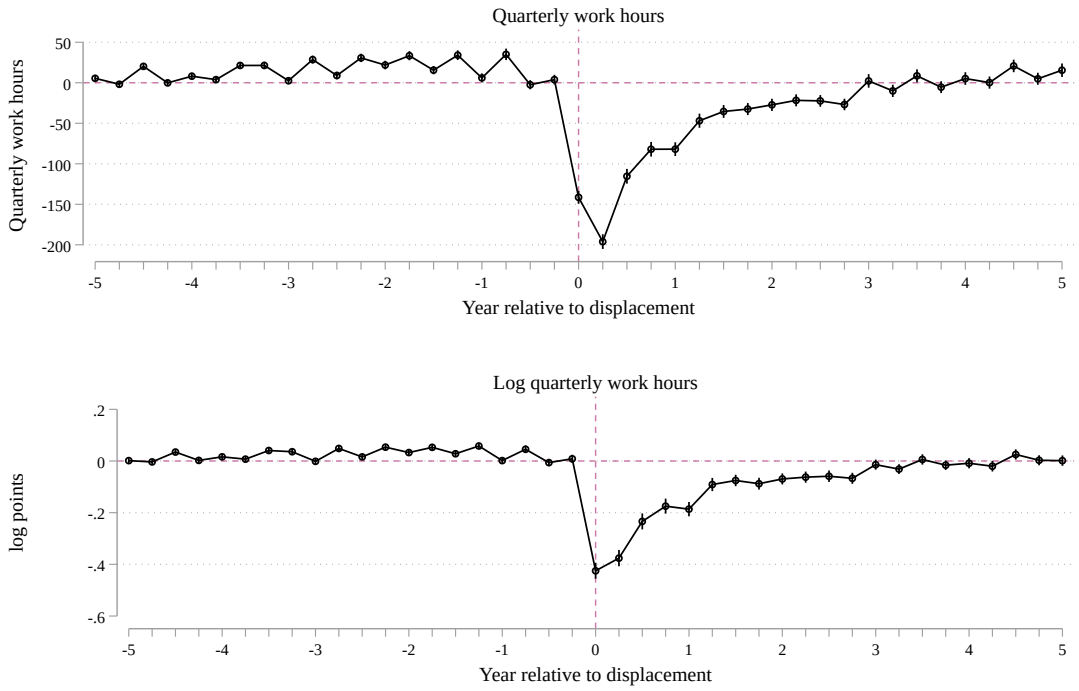
The three panels of Appendix Figure A10 show the estimated displacement losses due to employer fixed effects ($\widehat{\psi}_j$) when using the alternative comparison group—see the time paths marked with circles. (For comparison, the estimated full effects of displacement using the alternative comparison group are also shown as light squares. These are repeated from Appendix Figures A7–A9.) As was true in the analysis using the continuously employed comparison group, lost employer fixed effects account for a minimal portion of the total losses following displacement.

Appendix Figure A7
Earnings losses due to displacement estimated using the alternative comparison group



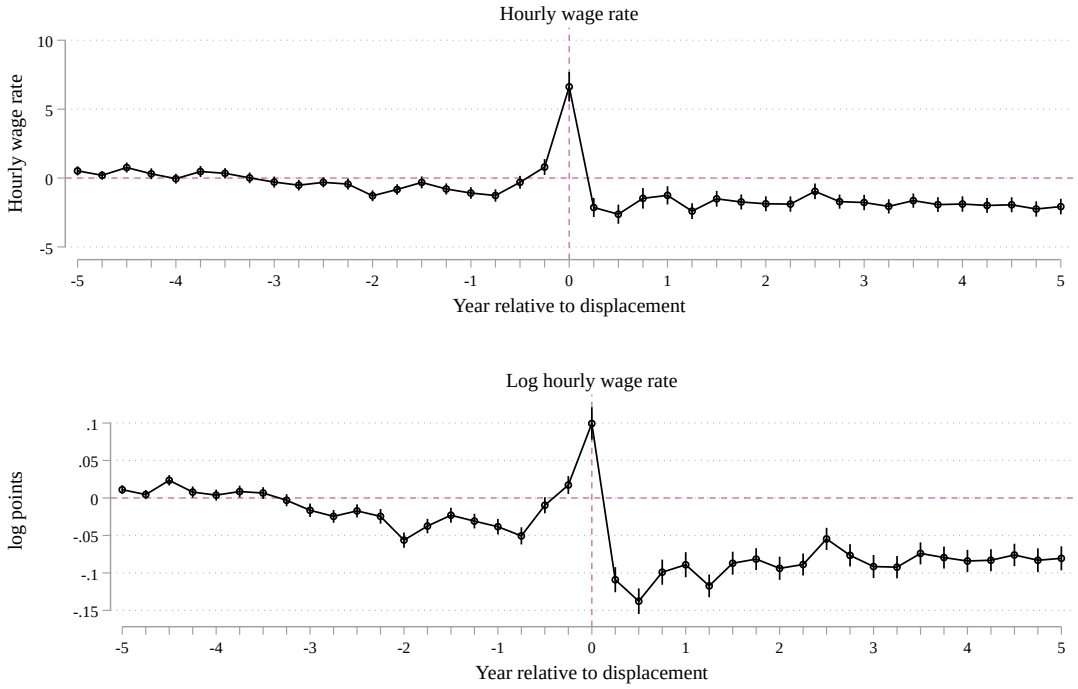
Notes: The figures show earnings losses estimated using a comparison group of long-tenure workers who were not displaced during 2008–2010, but who may have subsequently changed employers or separated from their primary employer (Krolikowski 2018). The top figure shows estimated δ_ks—quarterly unconditional earnings lost due to displacement (in constant 2010 $1,000s)—based on equation (1) with unconditional earnings from the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—log of quarterly earnings lost due to displacement—based on equation (1) with the log of earnings from the primary employer as the dependent variable. Whiskers (which are very small) denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See section 2.1 for details of the baseline comparison group, and see Figure 2 in the main text for estimates using the baseline comparison group.

Appendix Figure A8
Work hour losses due to displacement estimated using the alternative comparison group



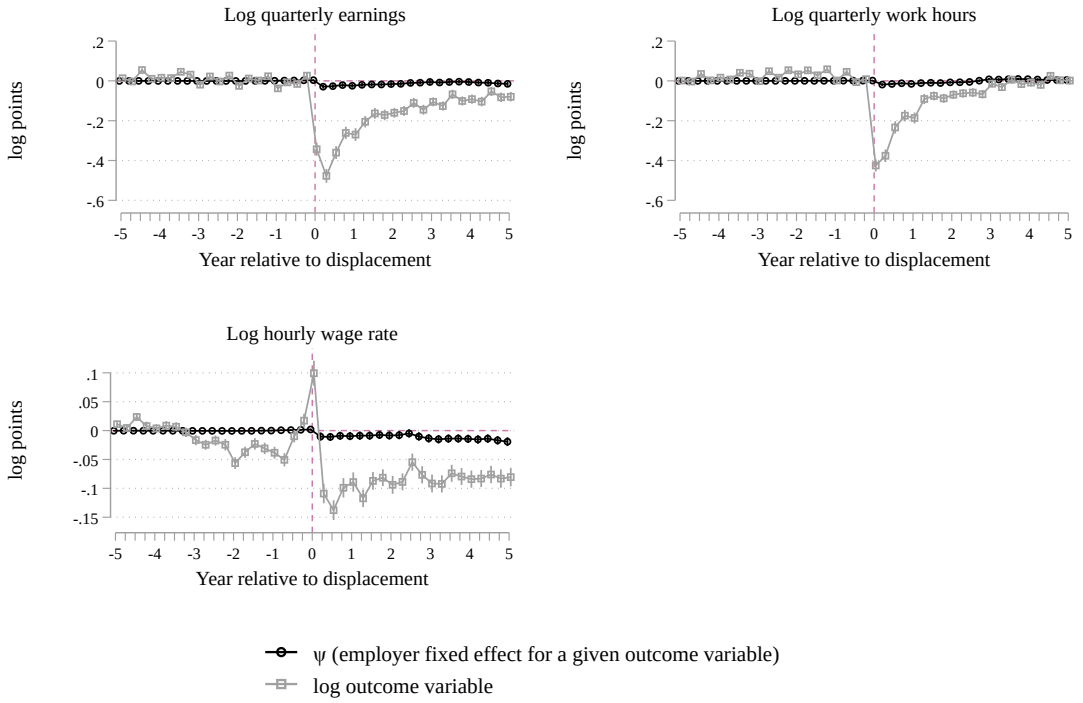
Notes: The figures show quarterly work hour losses estimated using a comparison group of long-tenure workers who were not displaced during 2008–2010, but who may have subsequently changed employers or separated from their primary employer (Krolikowski 2018). The top figure shows estimated δ_ks—quarterly unconditional hours lost due to displacement—based on equation (1) with unconditional hours from the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—log of quarterly hours lost due to displacement—based on equation (1) with the log of hours from the primary employer as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See section 2.1 for details of the baseline comparison group, and see Figure 3 in the main text for estimates using the baseline comparison group.

Appendix Figure A9
Hourly wage rate losses due to displacement estimated using the alternative comparison group



Notes: The figure shows hourly wage rate losses estimated using a comparison group of long-tenure workers who were not displaced during 2008–2010, but who may have subsequently changed employers or separated from their primary employer (Krolikowski 2018). The figure plots estimated δ_ks—the reduction in the log hourly wage rate due to displacement—based on equation (1) with the log of the hourly wage rate at the primary employer (constant 2010 dollars per hour) as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See section 2.1 for details of the baseline comparison group, and see Figure 5 in the main text for estimates using the baseline comparison group.

Appendix Figure A10
Estimated displacement losses due to lost employer fixed effects based on the alternative comparison group



Notes: The figures show estimated displacement losses attributable to foregone employer fixed effects (circles) compared with the full losses due to displacement (squares, repeated from Appendix Figures A7, A8, and A9). Losses attributable to foregone employer fixed effects are estimates of δ_k from equation (3). For example, to obtain the estimates of earnings lost due to foregone employer premiums, equation (3) was estimated with the AKM employer fixed effect ($\widehat{\psi}$) for log earnings as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See section 2.1 for details of the baseline comparison group, and see Figure 6 in the main text for estimates using the baseline comparison group.

Appendix A.5
Estimates from a broadened sample of displaced and non-displaced workers

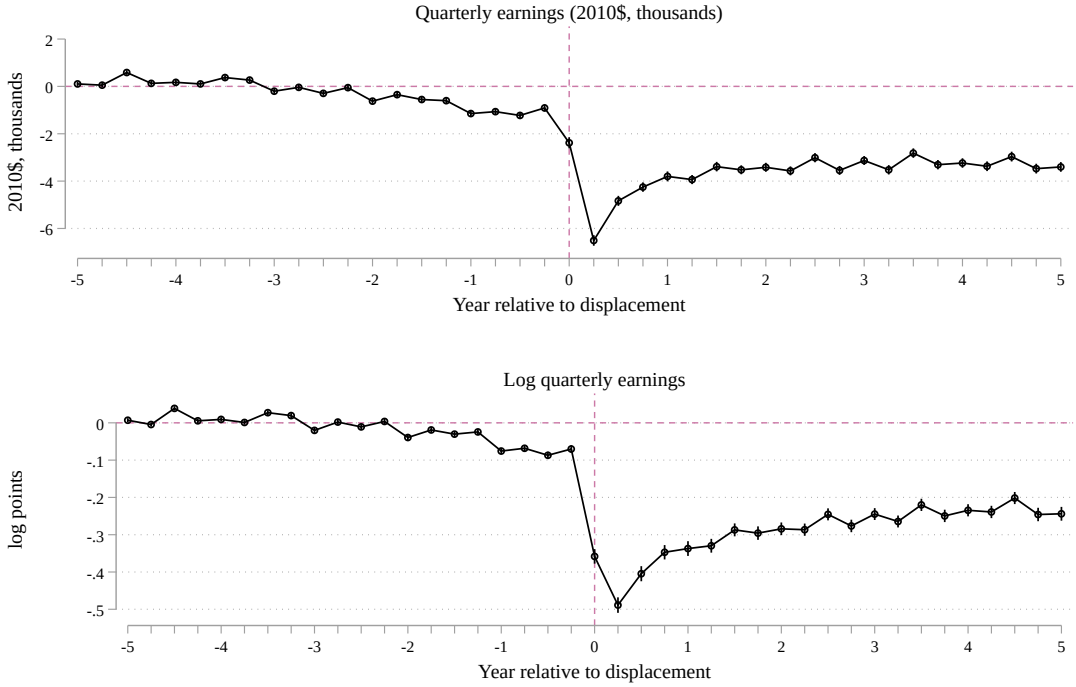
The estimates in the text are based on a sample of workers who claimed UI at least once during 2002–2014.[4] In this appendix, we present an analysis based on a broadened sample not restricted to UI claimants.

Appendix Figures A11, A12, and A13 repeat the analysis in the main text using all workers who satisfy the criteria for inclusion in the analysis sample described in section 2.1, except we no longer require them to have claimed UI at least once—see also row 6 of Appendix Table A1. This results in a substantially larger sample (6,170 displaced workers, and 257,651 workers in the comparison group), although it does not materially change the conclusions. The pre-displacement Ashenfelter dip is more noticeable in the broadened sample, and the initial drops in earnings, hours, and wage rates are somewhat less than in the original sample (comparing Appendix Figures A11–A13 with Figures 2, 3, and 5). But long-term losses appear to be somewhat greater in the broadened sample (23 log points in the broadened sample versus 16 log points in the sample restricted to UI claimants). The larger long-term earnings losses in the broadened sample occur mainly because wage rates in the broadened sample show little if any recovery from their drop at the time of displacement.

As in the main analysis, the employer fixed effects do not appear to account for much of the losses of this broadened sample.

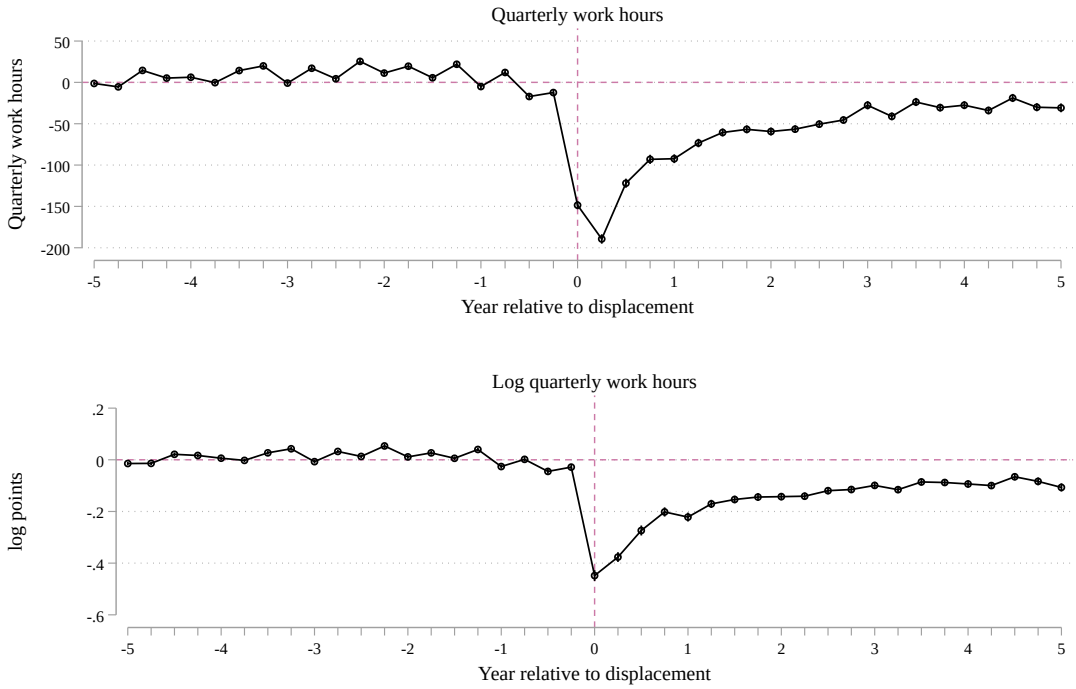
[4] As described in the text, this restriction is imposed on both the displaced workers and the comparison group for two reasons. First, we observe the individual characteristics of UI claimants, so we can restrict attention to displaced workers aged 20–50 at the time of displacement. Second, we can infer that non-displaced workers in the comparison group who claimed UI experienced at least one temporary layoff (an unemployment spell lasting less than one quarter and ending in recall to the same employer), creating a comparison group at greater risk of displacement and more comparable to the displaced treatment group.

Appendix Figure A11
Estimated earnings losses due to displacement, based on the broadened sample of displaced and non-displaced workers



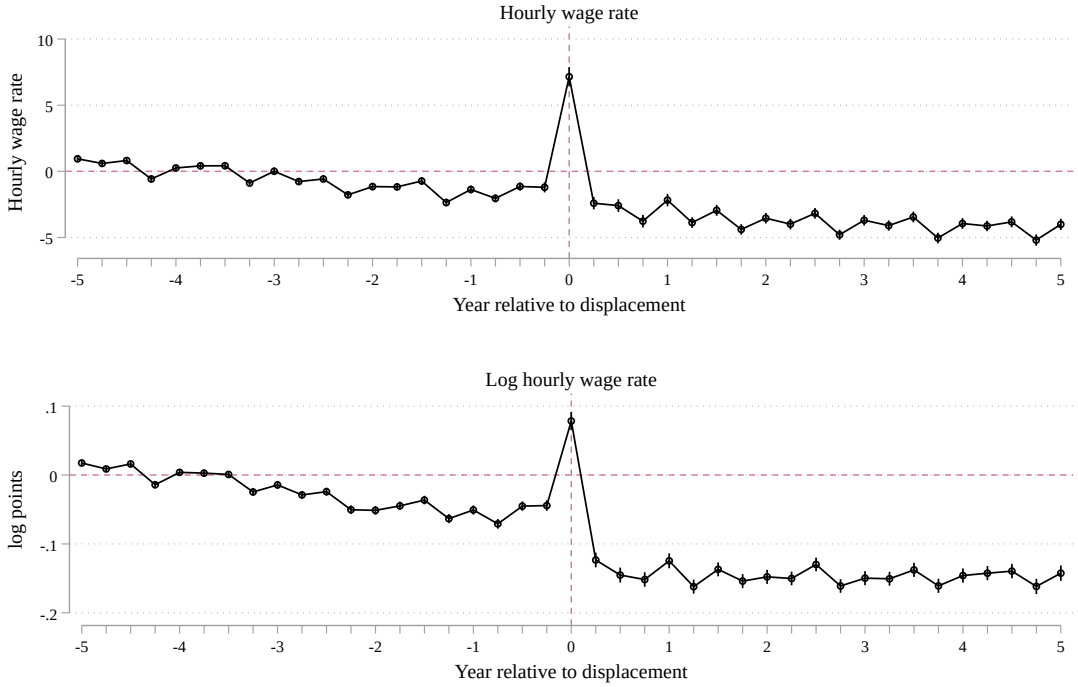
Notes: The figures show quarterly earnings losses estimated using the broadened sample of displaced and non-displaced workers—that is, without restricting the sample to workers who claimed UI at some time during 2002–2014. The top figure shows estimated δ_ks—quarterly unconditional earnings lost due to displacement (in constant 2010 $1,000s)—based on equation (1) with unconditional earnings from the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—log of quarterly earnings lost due to displacement—based on equation (1) with the log of earnings from the primary employer as the dependent variable. Whiskers (which are very small) denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage records.

Appendix Figure A12
Estimated work hour losses due to displacement, based on the broadened sample of displaced and non-displaced workers



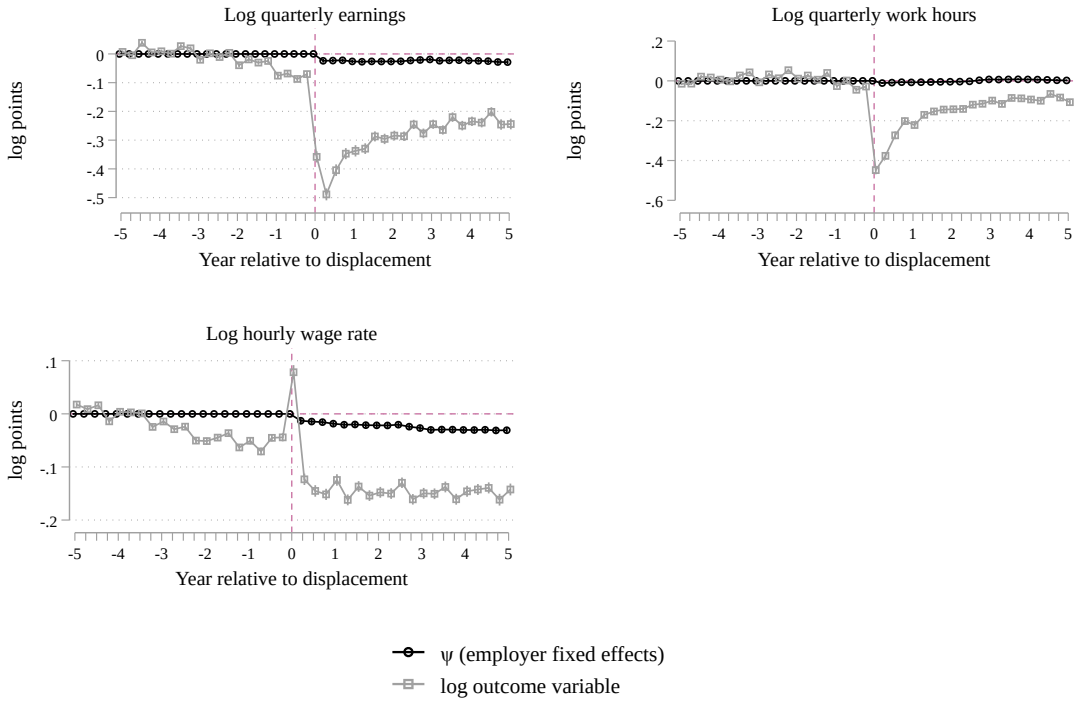
Notes: The figures show quarterly work hour losses estimated using the broadened sample of displaced and non-displaced workers—that is, without restricting the sample to workers who claimed UI at some time during 2002–2014. The top figure shows estimated δ_ks—quarterly unconditional hours lost due to displacement—based on equation (1) with unconditional hours at the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—log of quarterly hours lost due to displacement—based on equation (1) with the log of hours at the primary employer as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage records.

Appendix Figure A13
Estimated hourly wage rate losses due to displacement, based on the broadened sample of displaced and non-displaced workers



Notes: The figure shows hourly wage rate losses estimated using the broadened sample of displaced and non-displaced workers—that is, without restricting the sample to workers who claimed UI at some time during 2002–2014. The figure plots estimated δ_ks—reductions in the log hourly wage rate due to displacement—based on equation (1) with the log of the hourly wage rate at the primary employer (constant 2010 dollars per hour) as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage records.

Appendix Figure A14
Estimated displacement losses due to foregone employer fixed effects, based on the broadened sample of displaced and non-displaced workers



Notes: The figures show estimated displacement losses attributable to foregone employer fixed effects (circles) compared with the full losses due to displacement (squares, repeated from Figures A11, A12, and A13) for the broadened sample of displaced and non-displaced workers—that is, without restricting the sample to workers who claimed UI at some time during 2002–2014. Losses attributable to foregone employer fixed effects are estimates of δ_k from equation (3). For example, to obtain the estimates of earnings lost due to foregone employer premiums, equation (3) was estimated with the AKM employer fixed effect ($\widehat{\psi}$) for log earnings as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage records.

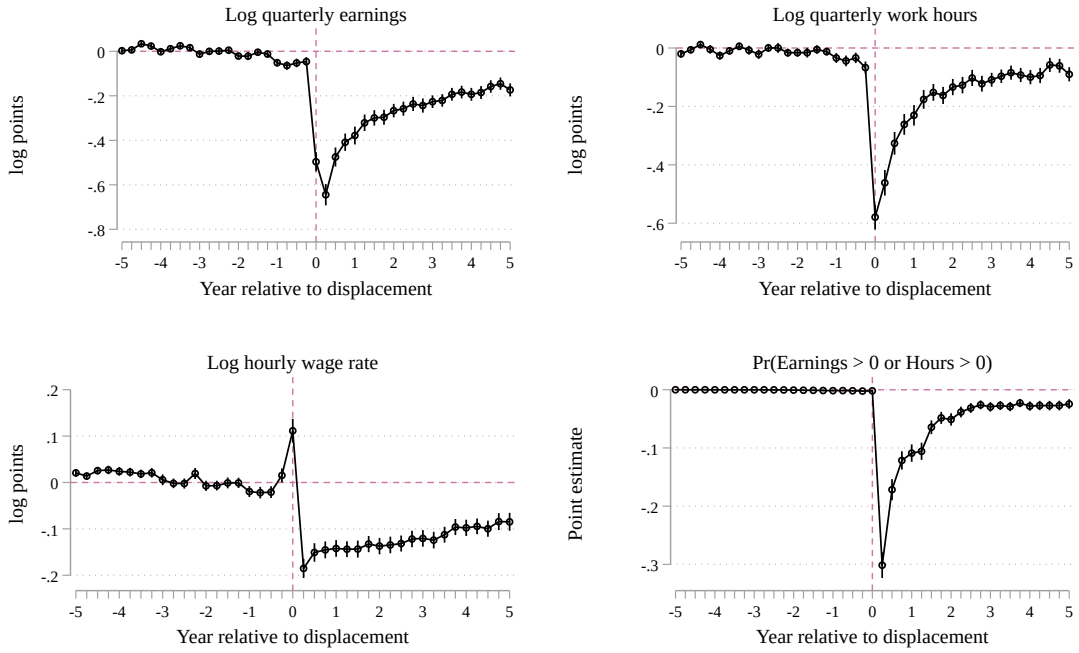
Appendix A.6
Estimates excluding workers displaced from NAICS industries 51–56

In this appendix, we repeat the main analysis *excluding* workers displaced from jobs in NAICS industries 51–56 (information, finance and insurance, real estate, professional, scientific, and technical services, management of companies; administrative, support, and waste management and remediation services). We do this for three reasons: first, as seen in Table 1 of the main text, workers in NAICS industries 51–56 have higher earnings and wage rates than other workers; second, the comparison sample for workers displaced from NAICS industries 51–56 is relatively thin, making inferences about the influence of displacement on these workers less convincing than for others; third, dropping NAICS industries 51–56 brings the industry composition of our analysis sample closer to the industry composition of the samples examined by JLS and CP.

Appendix Figure A15 plots the losses of workers displaced from industries other than NAICS 51–56—see also row 7 of Appendix Table A1. Immediate earnings losses are 65 log points, and long-term earnings losses (quarters 17–20) are 17 log points. For workers displaced from industries other than NAICS 51–56, then, both short- and long-term losses appear larger than for the full UI claimant sample. However, these long-term losses remain somewhat smaller than those estimated by JLS and CP for Pennsylvania and Connecticut.

Appendix Figure A15 shows that the long-term lost work hours of workers displaced from industries other than NAICS 51–56 also exceed those for workers overall. The long-term hours loss is about 8 log points (compared with 5 log points for the full UI claimant sample). The long-term wage reduction is about 10 log points (compared with 11 log points for the full UI claimant sample).

Appendix Figure A15
Estimated displacement effects for workers displaced from industries other than NAICS industries 51–56



Notes: The figures show estimated displacement effects for workers displaced from any industry *except* NAICS industries 51–56 (information, finance and insurance, real estate, professional, scientific, and technical services, management of companies; administrative, support, and waste management and remediation services). Each figure shows the profile of displacement effects for an outcome—log quarterly earnings, log quarterly hours, and log wage rate (all from the primary employer), or the probability of employment (positive earnings or hours)—based on estimates of δ_k in equation (1). Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records.

Appendix A.7
Estimates from a model with worker-specific trends (random trends model)

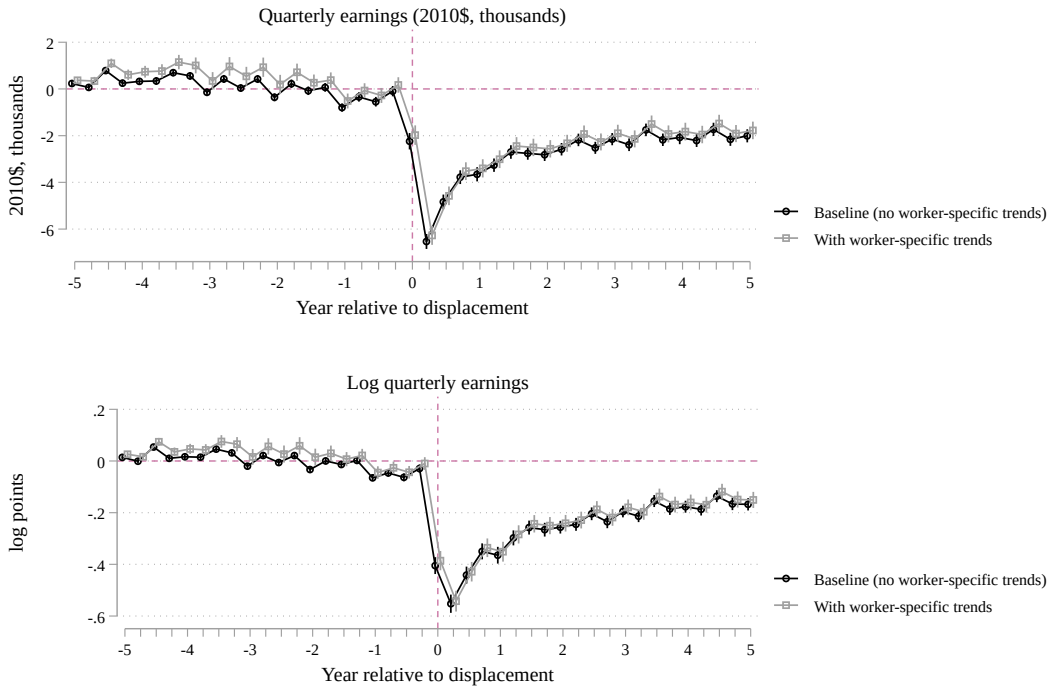
As a robustness check of the parallel-trends assumption, we estimate a version of the worker fixed-effects difference-in-differences model with worker-specific trends (a random trend model):

$$Y_{it} = c_i + \omega_i t + \gamma_t + \mathbf{Z}_{it}\boldsymbol{\theta}_1 + \mathbf{W}_{it}\boldsymbol{\theta}_2 + \mathbf{X}_{j(i,t)} + \sum_{k=-20}^{20}(\delta_k \cdot D_{itk}) + e_{it}\ , \qquad \text{(A.1)}$$

where t is a quarterly time trend, ω_i is a worker-specific quarterly growth rate over the period, and γ_t is a vector of calendar quarter indicators. [Other notation is the same as for equation (1) in the main text.] The worker-specific trends are included for the pre-displacement period, so as to account for any differential trends between displaced workers and the comparison group before displacement occurred.

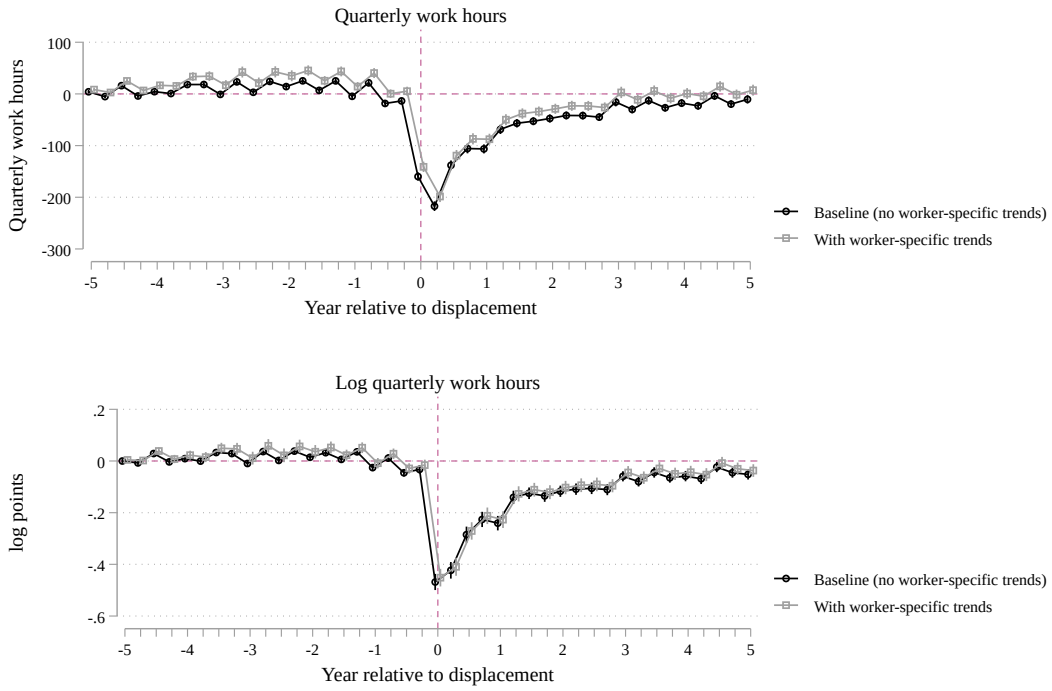
The results are shown in Appendix Figures A16, A17, and A18—see also row 8 of Appendix Table A1. The estimated profiles of earnings and hours are similar to those estimated using equation (1) and shown in Figures 2, 3, and 5. The overall similarity of the estimates suggests that pre-displacement earnings, work hours, and wage rates of displaced and non-displaced workers evolve approximately in parallel. This is consistent with interpreting the estimated δ_ks in equation (1) as displacement effects.

Appendix Figure A16
Estimated earnings losses due to displacement, based on the random-trends model



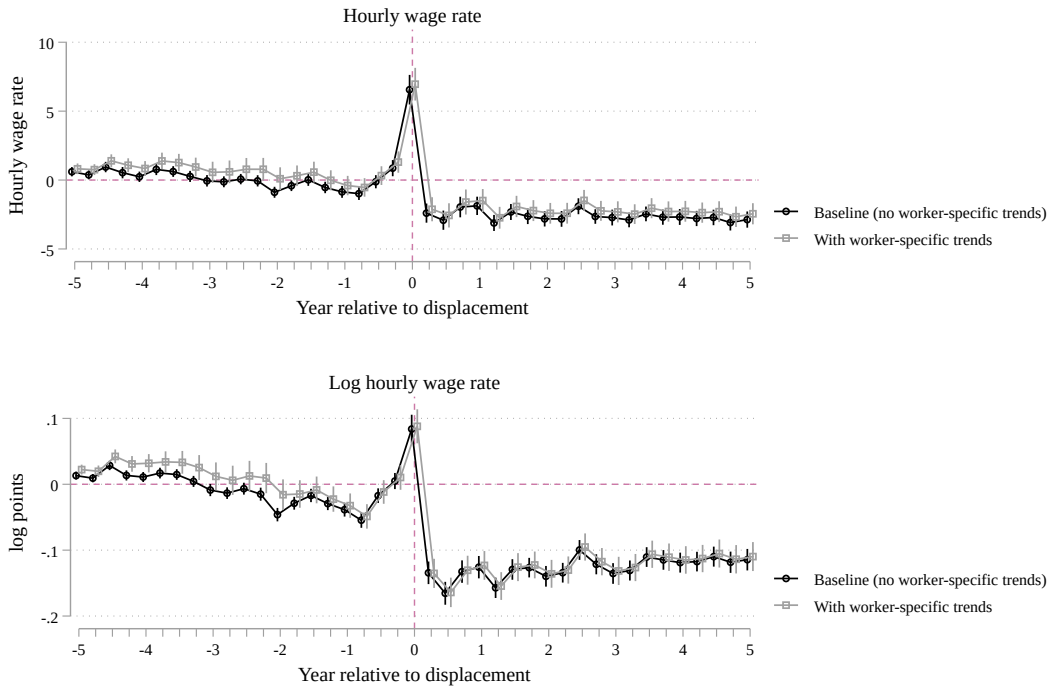
Notes: The top figure shows estimated δ_ks—quarterly unconditional earnings lost due to displacement (in constant 2010 $1,000s)—based on the random trend model [equation (A.1)] with unconditional earnings from the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—log of quarterly earnings lost due to displacement—based on equation (A.1) with the log of earnings from the primary employer as the dependent variable. Whiskers (which are very small) denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records.

Appendix Figure A17
Estimated work hour losses due to displacement, based on the random-trends model



Notes: The top figure shows estimated δ_ks—quarterly unconditional hours lost due to displacement—based on the random trend model [equation (A.1)] with unconditional hours at the primary employer as the dependent variable. The bottom figure shows estimated δ_ks—log of quarterly hours lost due to displacement—based on equation (A.1) with the log of hours at the primary employer as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records.

Appendix Figure A18
Estimated hourly wage rate losses due to displacement, based on the random-trends model



Notes: The figure shows estimated δ_ks—the reduction in the log hourly wage rate due to displacement—based on the random trend model [equation (A.1)] with the log of the hourly wage rate at the primary employer (constant 2010 dollars per hour) as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records.

Appendix A.8
Estimates using the specification and sampling choices of Schmieder, von Wachter, and Heining (2018)

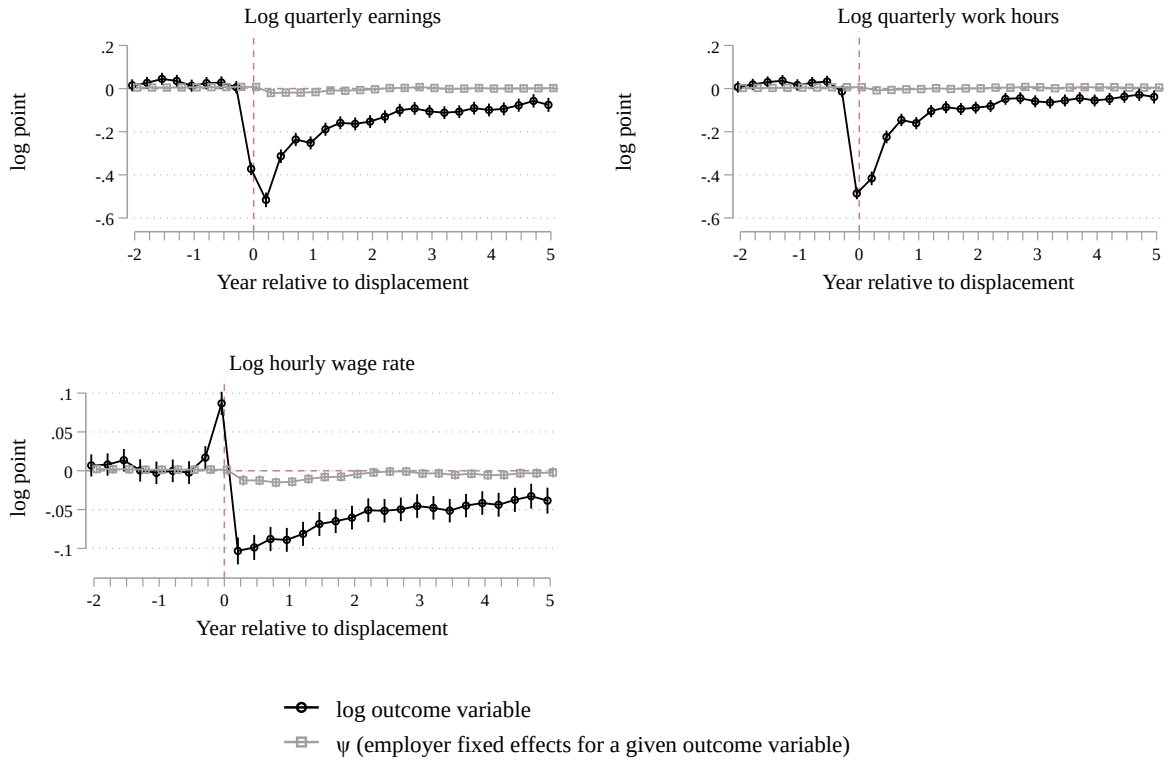
As noted in the main text (section 5.1), our finding that employer effects play such a limited role in displaced workers' losses is surprising in light of contrary findings by Schmieder, von Wachter, and Heining (2018) for Germany. In this appendix, we examine whether differences between their and our model specifications and sampling choices (definitions of the displaced workers and comparison groups) can explain the differences. Specifically, we make the following changes so as to conform with Schmieder, von Wachter, and Heining (2018):

- Include only full-time workers in the pre-displacement period (rather than part-time and full-time)
- Include only men (rather than women and men)
- Include workers aged 24–50 at displacement (rather than aged 20–50)
- Exclude workers in public administration and mining
- Include in the comparison group workers who separated from their employer (rather than require the comparison group to be continuously employed by the same employer)
- Use 1-1 closest-neighbor matching without replacement on the following pre-displacement characteristics: employer size (in 2007), average wage in t–2 (in 2006) and t–1 (in 2007), tenure, age, and education levels) within each one-digit pre-displacement industry
- Restrict the estimation sample to one control group worker for each displaced worker
- Add controls for age and education level to equations (1) and (3)

- Include in both the displaced worker sample and the comparison group workers with three or more years of job tenure (rather than restricting to six or more years of job tenure).

After making these modifications, we obtain the results displayed in Appendix Figure A19 using the Washington data (see also row 9 of Appendix Table A1). The three panels of Appendix Figure A19 show that employer fixed effects remain a negligible factor in explaining the losses of displaced workers. It follows that differences in model specification and sampling choices do not appear to underlie the different conclusions drawn by Schmieder, von Wachter, and Heining (2018) and by us. As we note in section 5.1, the disparities are more likely attributable to institutional differences between Germany and Washington State, possibly the greater importance of formal occupational training in Germany noted by Acemoglu and Pischke (1998).

Appendix Figure A19
Estimated displacement losses due to lost employer fixed effects: Model specifications and sampling choices of Schmieder, von Wachter, and Heining (2018) applied to the Washington data



Notes: The figures show estimated displacement losses attributable to foregone employer fixed effects (squares) compared with the full losses due to displacement (circles), using Schmieder, von Wachter, and Heining's (2018) model specifications and sampling choices. Losses attributable to foregone employer fixed effects are estimates of δ_k from equation (3). For example, to obtain the estimates of earnings lost due to foregone employer premiums, equation (3) was estimated with the AKM employer fixed effect ($\widehat{\psi}$) for log earnings as the dependent variable. Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.2 and 5.1 of the text and Appendix A.8 for details.

Appendix A.9
Changes in earnings and hours worked associated with inter-quintile employer effects transitions

Sections 5.2 and 5.4 of the main text presents a discussion of how changes in hourly wage rates, match effects, and direct effects are related to transitions made by displaced workers and non-displaced job changers among employers with different employer effects *for wage rates* (ψ). The discussion is built around Tables 4A, 4B, and 5, and Figures 7, 8A, 8B, and 8C. We focused on employer effects for wage rates because wage rates play a central role in explaining displaced workers' long-term earnings losses.

For completeness, this appendix includes tables and figures analogous to those in the main text, but pertaining to changes in employer effects (and associated outcomes) for *earnings* and *work hours*. Appendix Table A3 and Appendix Figures A20 and A21-1, A21-2, and A21-3 describe the outcomes (earnings, match effects, and direct effects) of displaced workers and non-displaced job changers as they transition among employers with different fixed effects *for earnings*. Appendix Table A4 and Appendix Figures A22 and A23-1, A23-2, and A23-3 do the same for transitions among employers with different fixed effects *for work hours.*

The conclusions to be drawn from the tables and figures in this appendix are similar to those described in section 5.2 and 5.4:

- The distributions of transition probabilities for displaced workers and non-displaced job changers differ markedly. The only notable difference from the results discussed in section 5.2 is the greater tendency of displaced workers to move to lower fixed effect employers for work hours than for either wage rates or earnings (see Appendix Table A4 (supplement)).

- For both displaced workers and non-displaced job changers, within-quintile transitions were more common than moves to higher- or lower-quintile employers. Again, the only notable difference pertains to employer effects for work hours, where the modal move for displaced workers is from a fifth-quintile to a fourth-quintile employer (see the bottom panel of Appendix Figure A22).
- Changes in employer effects for earnings and work hours do a reasonable job explaining the changes in earnings and work hours of non-displaced job changers as they move among employers with different fixed effects for earnings and work hours. This again suggests that the AKM model gives a reasonable description of the labor market—in this case of changes in earnings and work hours that accompany job mobility.
- In contrast, changes in employer effects for earnings and work hours do a poor job explaining the changes in earnings and work hours of displaced workers. If anything, these conclusions are stronger for moves to employers with different employer effects for earnings and work hours (see Appendix Tables A3 and A4) than was true for wage rates (Tables 4 and 5). Appendix Figures A21-1 and A23-1 highlight weak ability of changes in employer effects to explain displaced workers' reduced earnings and work hours.
- Figure 8A showed that lost wage rate match effects are less important for displaced workers who move to employers paying lower premiums than for the majority who move laterally or upward (Figure 8B). Appendix Figures A21-2 and A22-2 show the same is true for both earnings match effects and work hours match effects, and that the negative relationship is strongest for work hours. For non-displaced job changers, the relationship between $\Delta\mu$ for earnings and work hours and $\Delta\psi$ is much weaker, as was true for wage

rates: Employer effects play a dominant role in explaining earnings changes and work hours changes, and they do in explaining wage changes.

- As was true for wage rates, the direct effects of displacement (d) on earnings and work hours show little systematic variation with moves across employers paying different premium levels ($\Delta\psi$)—see Appendix Figures A21-3 and A22-3. Direct displacement losses vary greatly among workers, but not systematically with respect to the type of job transition. Non-displaced job changers also face substantial direct earnings penalties when they move (Appendix Figure A21-3), but no direct work hours penalty (Appendix Figure A23-3). It follows that the earnings penalty derives entirely from the direct wage rate penalty illustrated in Figure 8C of the main text.

Appendix Table A3
Inter-quintile employer fixed effect transitions, earnings changes, and employer fixed effect changes of displaced workers and non-displaced job changers, 2008–2010

Fixed-effect quintile of origin employer		Fixed-effect quintile of destination employer					Row sums and weighted averages
		1	2	3	4	5	
1	% of displaced workers in cell	4.9	1.7	1.3	0.9	0.7	9.6
	mean Δ earnings	-21.2	-43.4	-32.6	-19.1	13.2	-24.1
	mean Δ fixed effect	2.7	28.6	48.8	65.3	84.6	25.6
	% of AKM sample in cell	8.9	4.7	2.9	2.0	1.0	19.6
	mean Δ earnings	1.8	21.9	37.6	50.7	67.5	20.4
	mean Δ fixed effect	1.5	29.5	51.2	66.0	87.7	26.8
2	% of displaced workers in cell	1.7	3.6	1.3	0.9	0.1	7.5
	mean Δ earnings	-55.0	-36.1	-19.1	-25.4	25.3	-35.2
	mean Δ fixed effect	-26.9	0.6	17.5	31.8	74.0	2.3
	% of AKM sample in cell	3.6	8.6	4.0	2.4	1.2	19.7
	mean Δ earnings	-19.1	-0.7	10.6	23.1	41.6	3.6
	mean Δ fixed effect	-27.5	-1.7	16.4	33.1	55.3	4.8
3	% of displaced workers in cell	1.2	2.2	6.8	3.4	1.2	14.8
	mean Δ earnings	-82.8	-46.8	-30.6	-18.5	2.2	-31.8
	mean Δ fixed effect	-47.8	-15.7	-1.1	12.9	35.6	-0.9
	% of AKM sample in cell	1.6	3.3	6.5	6.2	2.1	19.7
	mean Δ earnings	-35.7	-12.1	0.4	9.7	29.2	1.4
	mean Δ fixed effect	-48.9	-18.3	-0.9	11.9	36.3	0.3
4	% of displaced workers in cell	1.7	1.9	5.4	9.1	4.9	23.0
	mean Δ earnings	-83.0	-55.6	-37.9	-24.6	-0.8	-29.5
	mean Δ fixed effect	-64.2	-34.4	-14.8	0.0	25.7	-5.6
	% of AKM sample in cell	0.8	1.6	4.1	10.3	4.5	21.3
	mean Δ earnings	-55.0	-26.7	-10.6	-0.5	15.1	-3.2
	mean Δ fixed effect	-66.5	-34.5	-14.4	0.1	20.0	-3.7
5	% of displaced workers in cell	0.6	0.9	3.2	9.6	30.8	45.1
	mean Δ earnings	-154.8	-110.6	-49.2	-26.1	-20.8	-27.6
	mean Δ fixed effect	-76.5	-57.3	-35.2	-14.9	-1.9	-9.2
	% of AKM sample in cell	0.4	0.7	1.4	3.7	13.6	19.8
	mean Δ earnings	-82.6	-47.1	-29.2	-14.8	0.5	-7.7
	mean Δ fixed effect	-87.4	-56.4	-34.6	-16.3	2.8	-7.3
Column sums and weighted averages	% of displaced workers	10.1	10.3	18.0	23.9	37.7	100.0
	mean Δ earnings	-52.7	-49.7	-35.5	-24.1	-16.7	-28.9
	mean Δ fixed effect	-24.3	-9.8	-6.3	-0.5	4.7	-2.9
	% of AKM sample	15.4	18.8	18.8	24.6	22.4	100.0
	mean Δ earnings	-12.2	-0.8	3.6	6.5	11.4	2.8
	mean Δ fixed effect	-16.5	-1.4	5.2	9.2	16.0	4.0

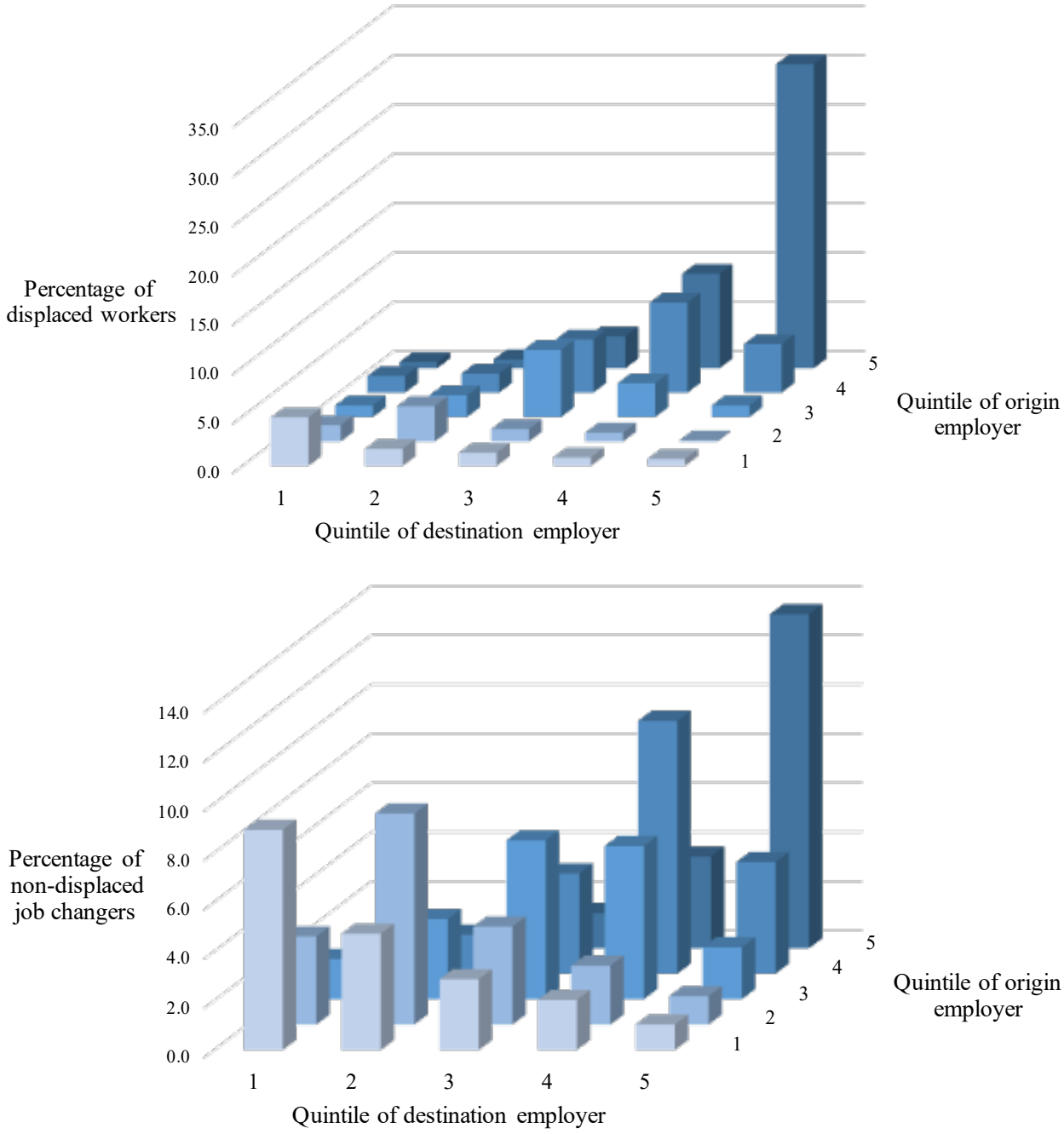
Note: This transition matrix shows the movement (and associated outcomes) of displaced workers and non-displaced job changers between employers with different fixed effects for quarterly earnings. Employers are classified into quintiles by their AKM-estimated fixed effects for earnings. The top three elements of each six-element cell show (i) the percentage of all displaced workers making the given quintile-to-quintile transition, (ii) the mean log-point change in earnings of those making that transition, and (iii) the mean change in the associated employer fixed effect of those making that transition. The bottom three elements of each cell show the same items for non-displaced job changers. Figures for both displaced workers and non-displaced job changers are based on a comparison of employment two years before and after the displacement or transition. See section 5.2 of the main text for further discussion.
Source: Authors' calculations based on the displaced worker sample described in the main text, and on primary job changes taking place during 2008–2010 in the AKM sample described in Appendix B.

Appendix Table A3 (supplement)
Below-, on-, and above-diagonal sums and weighted averages of inter-quintile transitions of displaced workers and non-displaced job changers, 2008–2010, earnings

	Below-diagonal sums and averages	On-diagonal sums and averages	Above-diagonal sums and averages
% of displaced workers	28.4	55.2	16.4
mean Δ earnings	-47.6	-23.6	-14.3
mean Δ fixed effect	-26.3	-0.9	30.6
% of non-displaced job changers	21.2	47.8	31.0
mean Δ earnings	-21.6	0.3	23.2
mean Δ fixed effect	-27.8	0.7	31.0

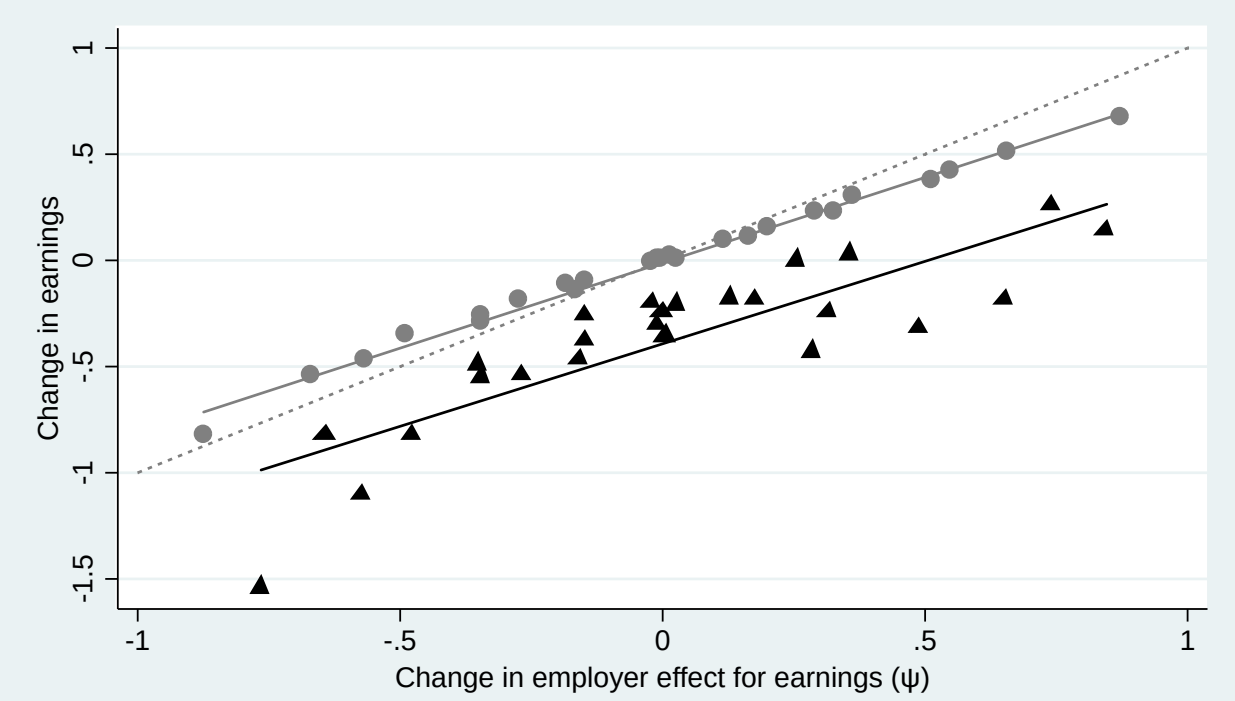
Note: Figures in the "Below-diagonal sums and averages" column show sums (or weighted averages of) the cells in the Appendix Table A3 transition matrix representing moves to an employer with a lower-quintile fixed effect for wage rates. Figures in the "On-diagonal" and "Above-diagonal" columns show sums or weighted averages of the cells in the Appendix Table A3 transition matrix representing moves to a same-quintile employer, or to a higher-quintile employer.
Source: Authors' calculations from data in Appendix Table A3 (main).

Appendix Figure A20
Inter-quintile employer earnings fixed effect transitions of displaced workers (top) and non-displaced job changers (bottom), 2008–2010, earnings



Note: The top histogram shows the percentage of displaced workers making each quintile-to-quintile transition.
Source: Data in Appendix Table A3.

Appendix Figure A21-1
Changes in earnings and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Note: For displaced workers the fitted equation is:

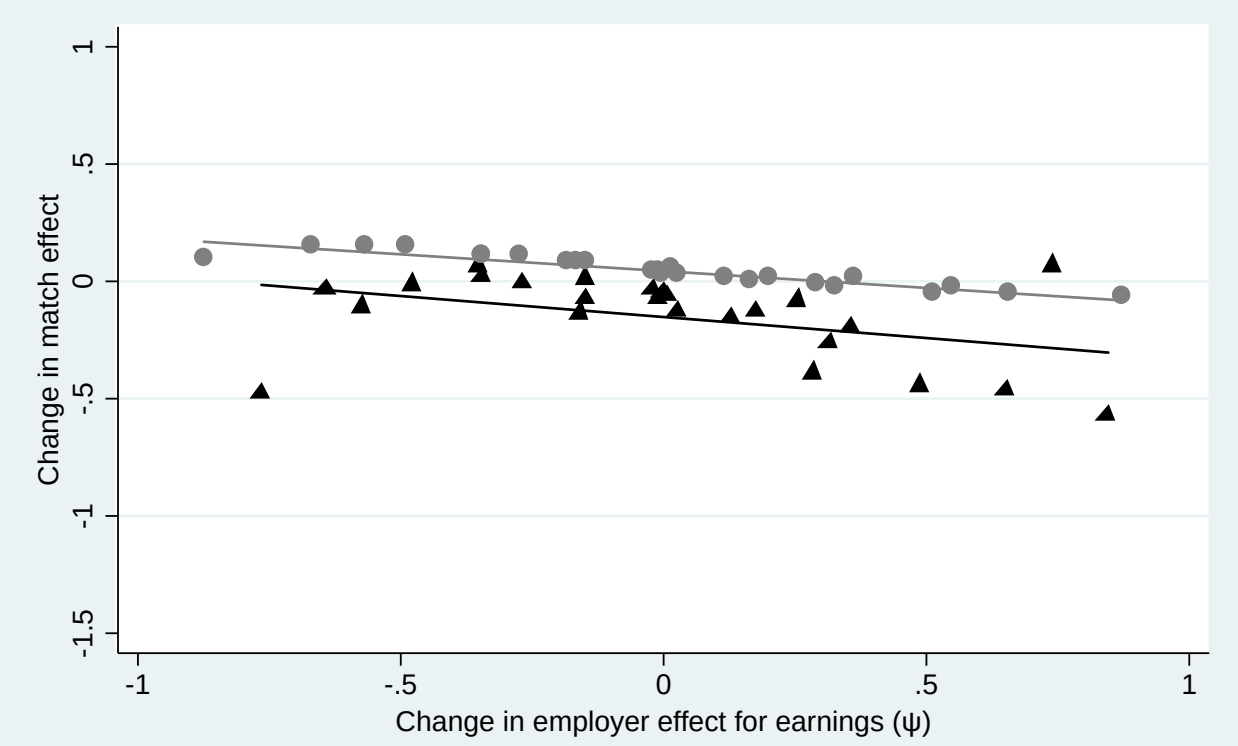
$\Delta earnings^{d} = -0.393 + 0.777\Delta\psi^{d}$ $R^2 = 0.725$, RMSE = 0.206, $n = 25$
(0.041) (0.010)

For non-displaced job changers the fitted linear equation is:

$\Delta earnings^{n} = -0.011 + 0.804\Delta\psi^{n}$ $R^2 = 0.992$, RMSE = 0.031, $n = 25$
(0.006) (0.015)

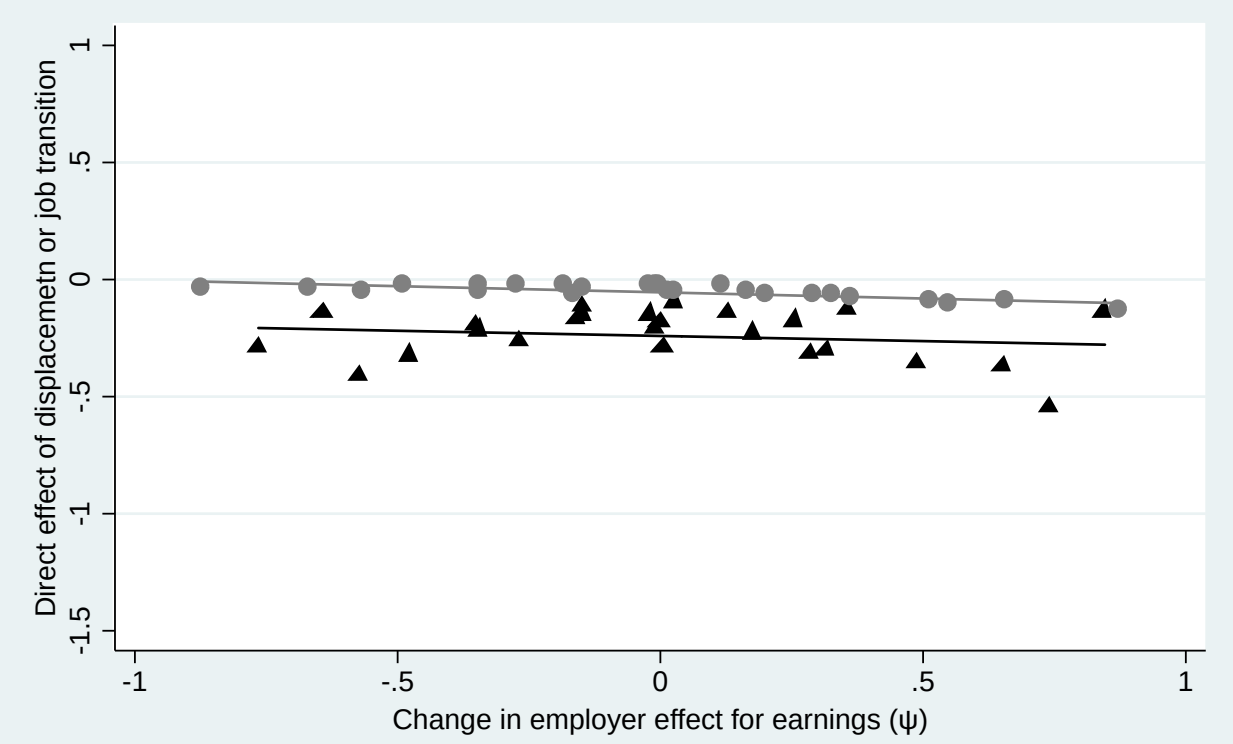
Source: Authors' calculations based on data in Table A3.

Appendix Figure A21-2
Changes in match effects (μ for earnings) and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Notes:
For displaced workers the fitted equation is:
$\Delta\mu^d = -0.152 - 0.179\Delta\psi^d$ $R^2 = 0.172$, RMSE = 0.170, $n = 25$
(0.034) (0.082)
For non-displaced job changers the fitted equation is:
$\Delta\mu^n = 0.044 - 0.143\Delta\psi^n$ $R^2 = 0.867$, RMSE = 0.024, $n = 25$
(0.005) (0.012)
Source: Authors' calculations.

Appendix Figure A21-3
Direct effects of displacement or job transition (*d* for earnings) and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Notes:
For displaced workers the fitted equation is:

$\Delta d^d = -0.241 - 0.044\Delta\psi^d$ $R^2 = 0.029$, RMSE = 0.110, $n = 25$
(0.022) (0.053)

For non-displaced job changers the fitted equation is:

$\Delta d^n = -0.055 - 0.053\Delta\psi^n$ $R^2 = 0.568$, RMSE = 0.020, $n = 25$
(0.004) (0.010)

Source: Authors' calculations.

Appendix Table A4
Inter-quintile employer fixed effect transitions, work hour changes, and employer fixed effect changes of displaced workers and non-displaced job changers, 2008–2010

Fixed-effect quintile of origin employer		Fixed-effect quintile of destination employer					Row sums and weighted averages
		1	2	3	4	5	
1	% of displaced workers in cell	4.9	2.5	1.0	1.1	1.2	10.6
	mean Δ work hours	-20.0	-12.8	-11.1	5.9	5.2	-12.1
	mean Δ fixed effect	-2.5	19.4	32.4	39.3	50.6	16.0
	% of non-displaced job changers	8.5	4.5	2.5	2.0	1.5	19.1
	mean Δ wage	0.4	19.7	32.9	41.1	52.9	17.7
	mean Δ fixed effect	0.7	23.7	37.9	45.1	54.5	20.0
2	% of displaced workers in cell	0.9	3.3	1.8	0.9	1.0	8.0
	mean Δ work hours	-23.7	-16.2	-5.2	-23.1	37.1	-8.8
	mean Δ fixed effect	-24.9	-0.4	9.6	17.4	27.9	4.7
	% of non-displaced job changers	3.4	5.7	4.4	3.1	2.3	19.0
	mean Δ work hours	-16.7	1.1	8.7	17.6	28.0	5.7
	mean Δ fixed effect	-22.2	-0.5	10.2	18.5	28.0	4.8
3	% of displaced workers in cell	1.6	2.6	7.7	4.3	3.1	19.3
	mean Δ work hours	-51.8	-26.7	-15.9	-8.3	3.0	-15.6
	mean Δ fixed effect	-37.9	-12.4	-0.4	7.0	13.7	-1.2
	% of non-displaced job changers	1.5	3.3	9.3	5.2	3.4	22.6
	mean Δ work hours	-32.1	-7.9	0.2	5.4	12.0	-0.1
	mean Δ fixed effect	-38.2	-11.2	0.3	6.6	13.9	-0.4
4	% of displaced workers in cell	0.7	1.2	3.1	6.0	4.8	15.8
	mean Δ work hours	-71.4	-30.4	-29.2	-11.9	-18.1	-21.4
	mean Δ fixed effect	-41.7	-18.1	-6.2	0.9	8.6	-1.6
	% of non-displaced job changers	1.0	1.9	3.8	6.7	5.8	19.2
	mean Δ work hours	-42.3	-15.2	-5.4	0.1	4.0	-3.5
	mean Δ fixed effect	-45.6	-19.2	-6.7	-0.1	5.7	-3.9
5	% of displaced workers in cell	1.4	1.6	4.1	26.8	12.5	46.3
	mean Δ work hours	-85.0	-29.7	-27.6	-14.7	-8.2	-16.7
	mean Δ fixed effect	-44.1	-23.8	-12.2	-4.8	0.9	-5.7
	% of non-displaced job changers	0.6	1.1	2.4	4.9	11.1	20.1
	mean Δ work hours	-57.7	-26.8	-14.0	-4.9	2.8	-4.5
	mean Δ fixed effect	-55.1	-27.8	-14.9	-6.1	1.9	-5.5
Column sums and weighted averages	% of displaced workers	9.5	11.2	17.6	39.1	22.6	100.0
	mean Δ work hours	-39.2	-21.3	-19.6	-13.2	-6.1	-16.1
	mean Δ fixed effect	-19.7	-3.9	-1.3	-0.9	8.1	-1.1
	% of non-displaced job changers	15.0	16.5	22.4	22.0	24.1	100.0
	mean Δ work hours	-11.9	0.6	3.0	6.5	10.0	2.8
	mean Δ fixed effect	-13.7	0.0	3.6	6.9	10.3	2.8

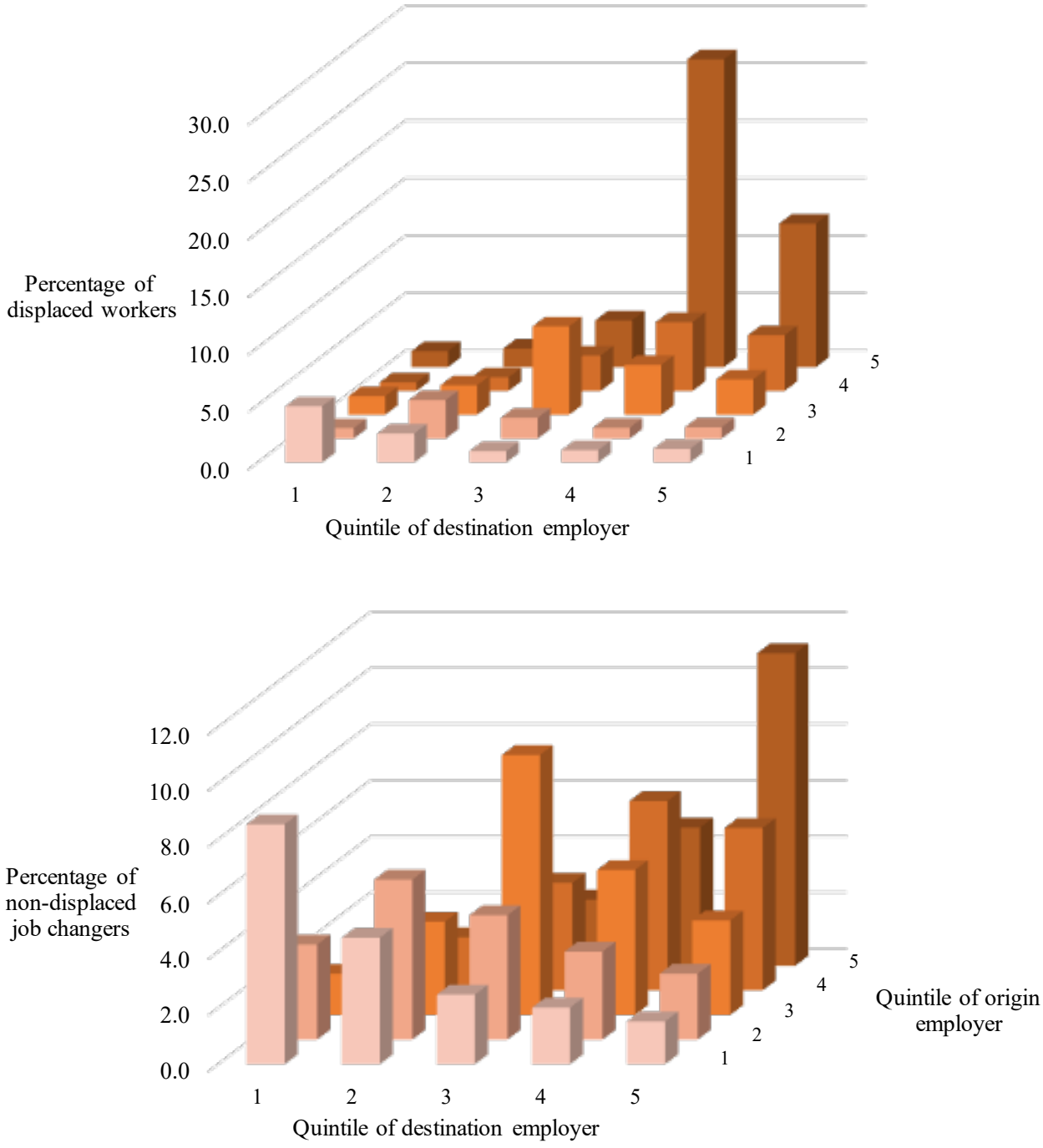
Note: This transition matrix shows the movement (and associated outcomes) of displaced workers and non-displaced job changers between employers with different fixed effects for quarterly work hours. Employers are classified into quintiles by their AKM-estimated fixed effects for work hours. The top three elements of each six-element cell show (i) the percentage of all displaced workers making the given quintile-to-quintile transition, (ii) the mean log-point change in work hours of those making that transition, and (iii) the mean change in the associated employer fixed effect of those making that transition. The bottom three elements of each cell show the same items for non-displaced job changers. Figures for both displaced workers and non-displaced job changers are based on a comparison of employment two years before and after the displacement or transition. See section 5.2 of the main text for further discussion.
Source: Authors' calculations based on the displaced worker sample described in the main text, and on primary job changes taking place during 2008–2010 in the AKM sample described in Appendix B.

Appendix Table A4 (supplement)
Below-, on-, and above-diagonal sums and weighted averages of inter-quintile transitions of displaced workers and non-displaced job changers, 2008–2010, work hours

	Below-diagonal sums and averages	On-diagonal sums and averages	Above-diagonal sums and averages
% of displaced workers	43.9	34.4	21.7
mean Δ hours	-23.3	-13.0	-6.5
mean Δ fixed effect	-10.6	0.0	16.4
% of non-displaced job changers	23.9	41.4	34.7
mean Δ hours	-14.4	1.1	16.8
mean Δ fixed effect	-17.0	0.6	18.9

Note: Figures in the "Below-diagonal sums and averages" column show sums (or weighted averages of) the cells in the Appendix Table A4 transition matrix representing moves to an employer with a lower-quintile fixed effect for wage rates. Figures in the "On-diagonal" and "Above-diagonal" columns show sums or weighted averages of the cells in the Appendix Table A4 transition matrix representing moves to a same-quintile employer, or to a higher-quintile employer.
Source: Authors' calculations from data in Appendix Table A4 (main).

Appendix Figure A22
Inter-quintile employer hours fixed effect transitions of displaced workers (top) and non-displaced job changers (bottom), 2008–2010, work hours



Note: The top histogram shows the percentage of displaced workers making each quintile-to-quintile transition.
Source: Data in Appendix Table A4.

Appendix Figure A23-1
Changes in work hours and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines

Note: For displaced workers the fitted equation is:

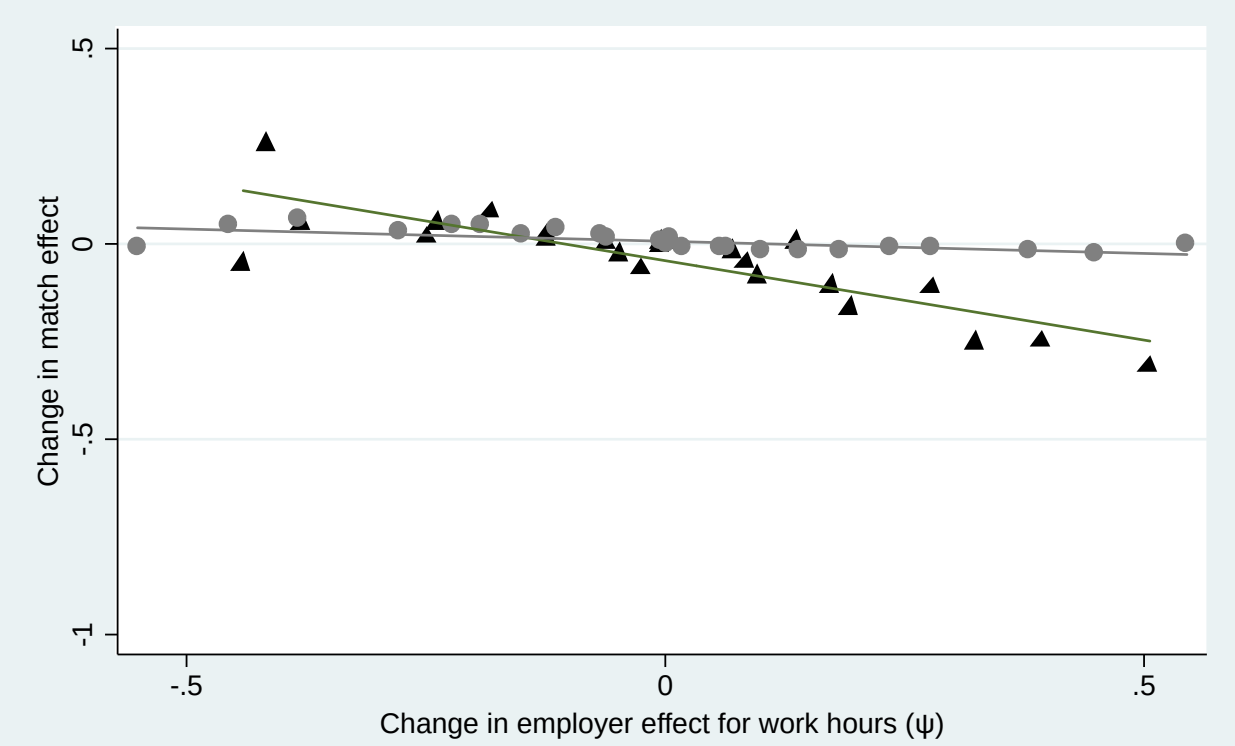
$\Delta hours^d = -0.195 + 0.839\Delta\psi^d$ $\quad R^2 = 0.698$, RMSE = 0.136, $n = 25$
(0.027) (0.015)

For non-displaced job changers the fitted linear equation is:

$\Delta hours^n = -0.002 + 0.932\Delta\psi^n$ $\quad R^2 = 0.993$, RMSE = 0.022, $n = 25$
(0.004) (0.017)

Source: Authors' calculations from the data in Table A4.

Appendix Figure A23-2
Changes in match effects (μ for work hours) and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines



Notes:
For displaced workers the fitted equation is:

$\Delta\mu^d = -0.043 - 0.407\Delta\psi^d$ $R^2 = 0.695$, RMSE = 0.066, $n = 25$
(0.013) (0.056)

For non-displaced job changers the fitted equation is:

$\Delta\mu^n = 0.007 - 0.062\Delta\psi^n$ $R^2 = 0.442$, RMSE = 0.019, $n = 25$
(0.004) (0.015)

Source: Authors' calculations.

Appendix Figure A23-3
Direct effects of displacement or job transition (*d* for work hours) and changes in employer effects (ψ) for displaced workers (triangles) and non-displaced job changers (circles): scatterplots with fitted regression lines

Notes:
For displaced workers the fitted equation is:

$\Delta d^d = -0.152 + 0.246\Delta\psi^d$ $R^2 = 0.054$, RMSE = 0.120, $n = 25$
(0.024) (0.101)

For non-displaced job changers the fitted equation is:

$\Delta d^n = -0.005 - 0.006\Delta\psi^n$ $R^2 = 0.016$, RMSE = 0.012, $n = 25$
(0.002) (0.009)

Source: Authors' calculations.

Appendix A.10
Alternative estimates of displacement losses due to lost match effects

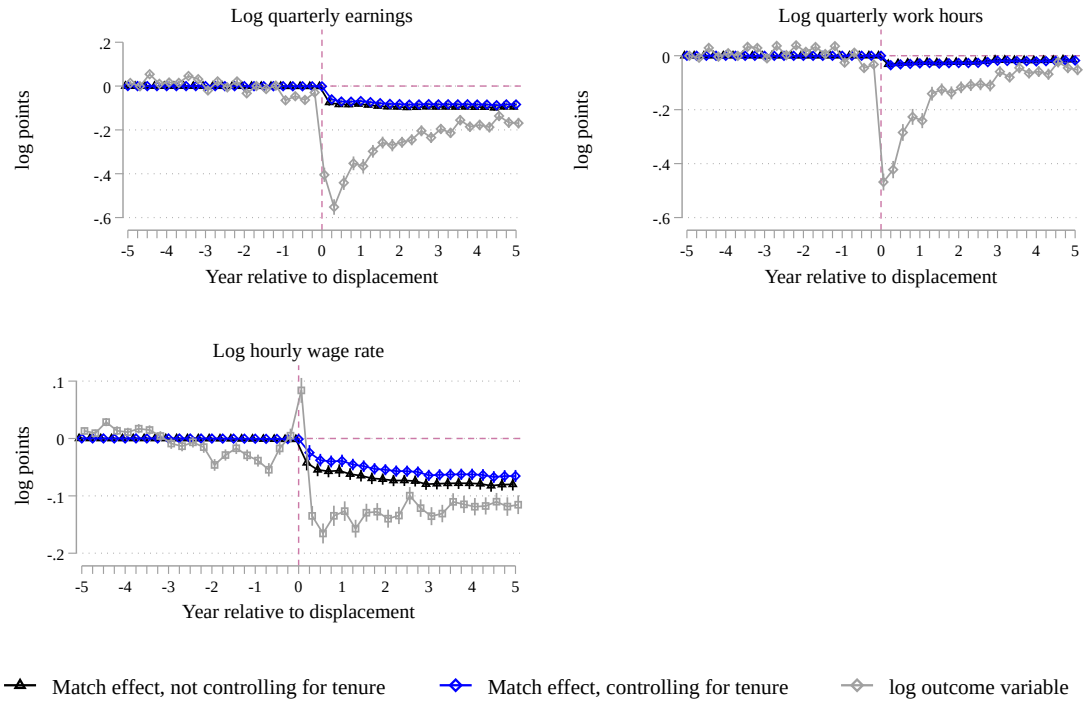
This appendix shows that, if we do not adjust the Woodcock match effects for job tenure, the estimated role of match effects in explaining displaced workers' losses is somewhat larger than if we do adjust (as in section 3.3). This is consistent with our expectations.

Section 3.3 outlined Woodcock's (2015) fixed effects match estimator, and section 5.4 described the resulting estimates. The residualized outcome variables ($\overline{\log Y_{ij}}$) used to obtain these estimates netted out the effects of job tenure, but because job tenure is endogenous with respect to worker, employer, and match quality, it seems wise to check whether the estimates are sensitive to this adjustment. Accordingly, we compute the average of the detrended outcome variable ($\overline{\log Y_{ij}}$) for each unique worker-employer match without netting out the contribution of job tenure.

The three panels of Appendix Figure A24 display the estimated displacement losses attributable to lost worker-employer match effects that adjust for years of job tenure ($\hat{\mu}$, denoted by diamonds and repeated from Figure 9 in the main text) and match effects that do not adjust for years of job tenure (denoted by triangles). For comparison, the three panels also display the full effects of displacement on log earnings, log hours, and log hourly wage rate (denoted by circles and repeated from the lower panels of Figures 2, 3, and 5 in the main text).

The estimates that do not adjust for job tenure suggest a somewhat larger role for match effects than the estimates that include the adjustment—compare rows 10 and 11 of Appendix Table A1. For example, the long-term wage rate loss due to match effects is about 6.5 log points after adjusting for job tenure, versus about 8 log points without the adjustment. This is expected because long-tenure workers have better matches, so not accounting for job tenure tends to overstate the role of match effects in explaining displaced workers' losses.

Appendix Figure A24
Estimated displacement losses attributable to lost worker-employer match effects (with and without controls for years of job tenure)



Notes: The figures show estimated displacement losses attributable to lost worker-employer match effects that adjust for years of job tenure ($\hat{\mu}$, denoted by diamonds and repeated from Figure 9 in the main text) and match effects that do not adjust for years of job tenure (denoted by triangles), compared with the full losses due to displacement (light circles). Whiskers denote 95-percent confidence intervals based on standard errors clustered by worker. The vertical lines denote the quarter of displacement.
Source: Authors' calculations using Washington administrative wage and claims records.

Appendix A.11
Tables supporting Figures 2, 3, 4, and 6 in the main text

Appendix Table A5 displays the estimates underlying Figure 2 in the main text. Column 1 corresponds to the upper panel of Figure 2 (earnings from the primary employer), and column 3 corresponds to the lower panel (log earnings from the primary employer). Columns 2 and 4 show estimates based on earnings from all employers, which are similar.

Appendix Table A6 displays the estimates underlying Figure 3 in the main text. Column 1 corresponds to the upper panel of Figure 3 (hours with the primary employer), and column 3 corresponds to the lower panel (log hours with the primary employer). Columns 2 and 4 show estimates based on hours from all employers, which are again similar to those based only on earnings from the primary employer.

Appendix Table A7 displays the estimates underlying Figure 4 in the main text. Column (1) shows estimated displacement effects on the probability of working a positive number of hours in a given quarter, based on estimates of equation (1). Columns (2)–(6) show estimated displacement effects on unconditional hours quantiles, obtained using the re-centered influence function approach (Firpo, Fortin, and Lemieux 2009).

Appendix Table A8 displays the estimates underlying Figure 6 in the main text. For each post-displacement quarter, the estimates in the odd-numbered columns give the total log-point losses of earnings (column 1), hours (column 3), and hourly wages (column 5) attributable to displacement, and the even-numbered columns give the log-point changes in earnings (column 2), hours (column 4), and hourly wages (column 6) attributable to the effect of displacement on moving to an employer with a different fixed effect for earnings, hours, or hourly wages.

Appendix Table A5
Estimated effects of displacement on unconditional earnings and log earnings (from primary employer and all employers), UI claimant sample

	(1)	(2)	(3)	(4)
	Quarterly earnings (constant 2010 dollars, thousands)		Log quarterly earnings	
Quarter relative to displacement	From primary employer only	From all employers	From primary employer only	From all employers
–20	0.233***	0.236***	0.014***	0.015***
	(0.059)	(0.060)	(0.004)	(0.004)
–19	0.065	0.064	-0.001	-0.001
	(0.066)	(0.067)	(0.005)	(0.005)
–18	0.788***	0.790***	0.054***	0.054***
	(0.072)	(0.073)	(0.005)	(0.005)
–17	0.248***	0.251***	0.010**	0.011**
	(0.078)	(0.078)	(0.005)	(0.005)
–16	0.324***	0.324***	0.016***	0.017***
	(0.073)	(0.074)	(0.005)	(0.005)
–15	0.342***	0.345***	0.015***	0.015***
	(0.085)	(0.086)	(0.005)	(0.005)
–14	0.697***	0.697***	0.046***	0.046***
	(0.079)	(0.080)	(0.005)	(0.005)
–13	0.559***	0.558***	0.031***	0.032***
	(0.082)	(0.082)	(0.006)	(0.006)
–12	-0.144*	-0.142*	-0.020***	-0.019***
	(0.081)	(0.082)	(0.006)	(0.006)
–11	0.429***	0.432***	0.021***	0.023***
	(0.087)	(0.088)	(0.006)	(0.006)
–10	0.038	0.063	-0.006	-0.003
	(0.082)	(0.083)	(0.006)	(0.006)
–9	0.425***	0.441***	0.021***	0.024***
	(0.088)	(0.088)	(0.006)	(0.006)
–8	-0.358***	-0.347***	-0.033***	-0.031***
	(0.086)	(0.086)	(0.006)	(0.006)
–7	0.224**	0.237***	0.000	0.003
	(0.091)	(0.092)	(0.007)	(0.007)
–6	-0.077	-0.061	-0.014**	-0.011*
	(0.093)	(0.094)	(0.006)	(0.006)
–5	0.067	0.085	0.002	0.005
	(0.094)	(0.094)	(0.006)	(0.006)
–4	-0.798***	-0.779***	-0.065***	-0.062***
	(0.090)	(0.090)	(0.007)	(0.007)
–3	-0.340***	-0.306***	-0.046***	-0.041***
	(0.103)	(0.104)	(0.007)	(0.008)
–2	-0.547***	-0.515***	-0.063***	-0.058***
	(0.105)	(0.105)	(0.008)	(0.008)
–1	-0.095	-0.039	-0.029***	-0.022***
	(0.113)	(0.114)	(0.008)	(0.008)
0	-2.239***	-1.218***	-0.405***	-0.312***

	(0.180)	(0.188)	(0.017)	(0.017)
1	-6.531***	-5.792***	-0.552***	-0.450***
	(0.163)	(0.174)	(0.018)	(0.018)
2	-4.834***	-4.617***	-0.442***	-0.410***
	(0.160)	(0.163)	(0.017)	(0.017)
3	-3.778***	-3.585***	-0.350***	-0.321***
	(0.150)	(0.152)	(0.016)	(0.016)
4	-3.655***	-3.477***	-0.365***	-0.338***
	(0.155)	(0.158)	(0.017)	(0.016)
5	-3.263***	-3.091***	-0.298***	-0.272***
	(0.146)	(0.147)	(0.015)	(0.015)
6	-2.700***	-2.552***	-0.258***	-0.234***
	(0.148)	(0.148)	(0.014)	(0.014)
7	-2.757***	-2.634***	-0.266***	-0.246***
	(0.139)	(0.139)	(0.014)	(0.013)
8	-2.817***	-2.687***	-0.256***	-0.236***
	(0.136)	(0.137)	(0.013)	(0.012)
9	-2.581***	-2.442***	-0.245***	-0.225***
	(0.136)	(0.137)	(0.013)	(0.013)
10	-2.182***	-2.034***	-0.204***	-0.182***
	(0.137)	(0.137)	(0.013)	(0.012)
11	-2.522***	-2.096***	-0.235***	-0.189***
	(0.131)	(0.132)	(0.013)	(0.012)
12	-2.150***	-2.019***	-0.196***	-0.177***
	(0.133)	(0.133)	(0.011)	(0.011)
13	-2.390***	-2.200***	-0.214***	-0.189***
	(0.138)	(0.138)	(0.012)	(0.011)
14	-1.753***	-1.586***	-0.155***	-0.136***
	(0.137)	(0.139)	(0.012)	(0.012)
15	-2.176***	-2.006***	-0.185***	-0.166***
	(0.136)	(0.137)	(0.012)	(0.012)
16	-2.077***	-1.942***	-0.177***	-0.157***
	(0.147)	(0.147)	(0.012)	(0.011)
17	-2.209***	-2.034***	-0.187***	-0.163***
	(0.141)	(0.142)	(0.012)	(0.012)
18	-1.730***	-1.573***	-0.136***	-0.117***
	(0.144)	(0.144)	(0.012)	(0.012)
19	-2.158***	-2.017***	-0.166***	-0.148***
	(0.142)	(0.143)	(0.012)	(0.012)
20	-2.008***	-1.878***	-0.168***	-0.149***
	(0.143)	(0.143)	(0.012)	(0.012)
Number of worker-quarter observations	811,141	811,141	808,058	808,058
Number of workers	15,980	15,980	15,980	15,980
R^2	0.095	0.091	0.086	0.081

Notes: Columns (1) and (3) show the coefficients (and standard errors clustered by worker) underlying Figure 2 in the main text. These are estimated δ_ks from equation (1) with the log of earnings from the primary employer as the dependent variable. Each regression controls for a worker-specific fixed effect; a vector of quarterly dummies; worker's age and age squared; a vector of gender, race, and education dummies interacted with the worker's age;

logarithm of pre-displacement employer size and one-digit NAICS code in 2007:IV interacted with a vector of yearly dummies; a simple average of pre-displacement earnings with the primary employer and an average of pre-displacement hours with the primary employer, each interacted with a vector of yearly dummies. Earnings are expressed in 2010-constant dollars.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Appendix Table A6
Estimated effects of displacement on unconditional hours and log hours (from primary employer and all employers), UI claimant sample

	(1)	(2)	(3)	(4)
	Quarterly work hours		Log quarterly work hours	
Quarter relative to displacement	From primary employer only	From all employers	From primary employer only	From all employers
–20	4.195**	4.082**	-0.000	0.000
	(1.777)	(1.841)	(0.005)	(0.005)
–19	-5.173***	-5.617***	-0.007	-0.009*
	(1.774)	(1.848)	(0.005)	(0.005)
–18	16.000***	16.123***	0.029***	0.030***
	(2.084)	(2.183)	(0.005)	(0.005)
–17	-3.952*	-3.737*	-0.003	-0.003
	(2.024)	(2.125)	(0.006)	(0.006)
–16	4.351**	4.161*	0.009	0.009
	(2.126)	(2.220)	(0.006)	(0.006)
–15	0.761	0.609	-0.000	-0.001
	(2.070)	(2.155)	(0.006)	(0.006)
–14	18.172***	18.474***	0.033***	0.033***
	(2.230)	(2.337)	(0.006)	(0.006)
–13	18.231***	18.107***	0.029***	0.029***
	(2.354)	(2.430)	(0.006)	(0.006)
–12	-0.922	-0.771	-0.010	-0.009
	(2.293)	(2.398)	(0.006)	(0.006)
–11	23.327***	23.652***	0.037***	0.037***
	(2.485)	(2.581)	(0.006)	(0.006)
–10	3.194	5.155**	0.002	0.005
	(2.435)	(2.568)	(0.006)	(0.006)
–9	24.136***	25.391***	0.038***	0.041***
	(2.619)	(2.740)	(0.006)	(0.006)
–8	14.205***	14.906***	0.014**	0.015**
	(2.725)	(2.837)	(0.006)	(0.006)
–7	25.367***	26.187***	0.032***	0.033***
	(2.813)	(2.917)	(0.007)	(0.007)
–6	6.913***	8.080***	0.006	0.007
	(2.573)	(2.693)	(0.006)	(0.006)
–5	25.185***	26.821***	0.035***	0.038***
	(2.949)	(3.061)	(0.006)	(0.006)
–4	-4.582	-2.223	-0.026***	-0.022***
	(2.809)	(2.955)	(0.007)	(0.007)
–3	21.578***	24.504***	0.011	0.015*
	(3.589)	(3.722)	(0.008)	(0.008)
–2	-18.385***	-16.046***	-0.046***	-0.042***
	(2.969)	(3.088)	(0.007)	(0.007)
–1	-13.501***	-9.418***	-0.033***	-0.028***
	(3.124)	(3.302)	(0.008)	(0.008)
0	-159.869***	-112.422***	-0.468***	-0.341***
	(4.057)	(4.392)	(0.016)	(0.015)

1	-217.212***	-191.846***	-0.423***	-0.336***
	(4.749)	(5.206)	(0.016)	(0.016)
2	-138.115***	-130.265***	-0.285***	-0.255***
	(4.768)	(4.911)	(0.016)	(0.015)
3	-105.666***	-96.448***	-0.226***	-0.196***
	(4.749)	(4.907)	(0.015)	(0.015)
4	-106.383***	-98.573***	-0.241***	-0.218***
	(4.460)	(4.635)	(0.014)	(0.014)
5	-68.623***	-59.599***	-0.141***	-0.118***
	(4.557)	(4.719)	(0.013)	(0.013)
6	-56.753***	-49.576***	-0.125***	-0.103***
	(4.136)	(4.280)	(0.011)	(0.011)
7	-52.836***	-46.115***	-0.135***	-0.116***
	(3.911)	(4.040)	(0.012)	(0.012)
8	-47.530***	-40.532***	-0.117***	-0.098***
	(3.977)	(4.110)	(0.011)	(0.011)
9	-41.651***	-34.077***	-0.109***	-0.091***
	(3.859)	(4.062)	(0.011)	(0.011)
10	-41.909***	-32.788***	-0.106***	-0.080***
	(3.773)	(3.917)	(0.011)	(0.011)
11	-44.909***	-21.525***	-0.111***	-0.062***
	(3.720)	(3.932)	(0.011)	(0.011)
12	-15.717***	-8.061*	-0.059***	-0.040***
	(4.257)	(4.322)	(0.010)	(0.010)
13	-29.960***	-20.093***	-0.080***	-0.056***
	(3.849)	(3.980)	(0.010)	(0.010)
14	-12.760***	-4.747	-0.044***	-0.027***
	(3.994)	(4.106)	(0.010)	(0.010)
15	-26.738***	-18.313***	-0.065***	-0.044***
	(3.722)	(3.856)	(0.010)	(0.009)
16	-17.750***	-9.650**	-0.058***	-0.039***
	(3.918)	(4.057)	(0.010)	(0.010)
17	-22.954***	-12.953***	-0.069***	-0.046***
	(3.817)	(3.952)	(0.011)	(0.010)
18	-3.708	5.132	-0.024**	-0.007
	(3.887)	(4.029)	(0.010)	(0.010)
19	-19.699***	-12.646***	-0.045***	-0.029***
	(3.783)	(3.917)	(0.010)	(0.010)
20	-10.467**	-2.555	-0.052***	-0.032***
	(4.136)	(4.269)	(0.010)	(0.010)
Number of worker-quarter observations	811,141	811,141	804,437	804,687
Number of workers	15,980	15,980	15,980	15,980
R^2	0.109	0.097	0.056	0.051

Notes: Columns (1) and (3) show the coefficients (and standard errors clustered by worker) underlying Figure 3 in the main text. These are estimated δ_ks from equation (1) with the log of hours from the primary employer as the dependent variable. Each regression controls for a worker-specific fixed effect; a vector of quarterly dummies; worker's age and age squared; a vector of gender, race, and education dummies interacted with the worker's age; logarithm of pre-displacement employer size and one-digit NAICS code in 2007:IV interacted with a vector of

yearly dummies; a simple average of pre-displacement earnings with the primary employer and an average of pre-displacement hours with the primary employer, each interacted with a vector of yearly dummies
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3.1, 4.1, and 4.2 of the text for details.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Appendix Table A7
Estimated displacement effects on the probability of positive work hours and the distribution of quarterly work hours, UI claimant sample

	(1)	(2)	(3)	(4)	(5)	(6)
Quarter relative to displacement	Pr(hours > 0)	Hours quantile 10th	25th	50th	75th	90th
–20	0.002	-11.19	-1.89	2.84	11.03	20.33
	(0.001)	(5.07)	(2.59)	(1.00)	(2.17)	(4.45)
–19	0.003	13.42	-4.90	-3.36	-15.15	-18.03
	(0.001)	(5.08)	(2.84)	(1.04)	(2.14)	(3.82)
–18	0.004	7.00	7.53	9.22	20.07	32.61
	(0.002)	(5.45)	(2.64)	(1.08)	(2.35)	(4.76)
–17	-0.001	2.46	-1.52	0.19	-4.23	-19.29
	(0.002)	(5.66)	(2.70)	(1.08)	(2.36)	(4.27)
–16	-0.002	-13.79	-5.53	1.79	14.02	27.65
	(0.002)	(5.90)	(2.89)	(1.10)	(2.36)	(4.94)
–15	0.004	0.30	1.68	1.92	1.22	-5.76
	(0.002)	(5.73)	(2.83)	(1.07)	(2.46)	(4.62)
–14	0.002	8.28	14.93	7.94	18.91	45.68
	(0.002)	(5.60)	(2.75)	(1.14)	(2.58)	(5.43)
–13	0.003	4.14	8.81	7.05	23.23	44.79
	(0.002)	(5.71)	(2.78)	(1.10)	(2.57)	(5.65)
–12	0.002	-8.42	3.75	-1.76	-3.36	-2.31
	(0.002)	(5.86)	(2.82)	(1.18)	(2.60)	(4.97)
–11	0.001	-0.60	13.45	9.18	25.75	52.05
	(0.002)	(5.93)	(2.85)	(1.13)	(2.62)	(5.68)
–10	-0.000	-1.11	5.07	-2.71	-0.94	6.89
	(0.002)	(6.01)	(2.89)	(1.21)	(2.72)	(5.27)
–9	-0.001	-5.95	10.90	5.49	22.53	58.90
	(0.002)	(6.24)	(2.91)	(1.14)	(2.66)	(5.79)
–8	0.000	-10.67	1.75	-1.42	7.58	39.97
	(0.002)	(6.19)	(2.97)	(1.23)	(2.75)	(5.69)
–7	-0.001	1.39	8.78	7.15	22.01	47.64
	(0.002)	(5.99)	(2.98)	(1.21)	(2.68)	(5.62)
–6	-0.001	0.13	4.26	-3.13	-1.14	16.19
	(0.002)	(6.15)	(3.07)	(1.25)	(2.64)	(4.98)
–5	-0.001	-6.41	9.36	4.32	16.28	48.50
	(0.002)	(6.47)	(3.06)	(1.20)	(2.58)	(5.64)
–4	-0.003	-23.80	-15.63	-8.62	-8.34	19.31
	(0.002)	(6.86)	(3.31)	(1.26)	(2.62)	(5.25)
–3	-0.005	-27.39	-5.22	1.50	14.99	44.14
	(0.002)	(6.90)	(3.31)	(1.24)	(2.71)	(5.74)
–2	-0.009	-41.06	-17.88	-11.10	-14.81	-4.07
	(0.003)	(7.69)	(3.56)	(1.32)	(2.58)	(4.60)
–1	-0.019	-64.02	-14.56	0.50	6.97	13.97
	(0.003)	(8.64)	(3.68)	(1.28)	(2.67)	(5.02)
0	-0.074	-502.87	-165.38	-31.69	-34.70	-15.77
	(0.005)	(13.15)	(4.09)	(1.23)	(2.28)	(4.23)
1	-0.256	-590.50	-206.74	-38.78	-32.61	-17.61
	(0.009)	(13.35)	(3.93)	(1.17)	(2.23)	(3.99)
2	-0.155	-378.91	-109.00	-22.35	-25.86	-7.22
	(0.008)	(13.10)	(4.40)	(1.32)	(2.36)	(4.42)
3	-0.120	-315.11	-75.52	-10.88	-26.31	-12.69
	(0.007)	(12.76)	(4.38)	(1.34)	(2.40)	(4.46)
4	-0.107	-288.09	-92.98	-22.69	-21.12	-5.14

	(0.006)	(12.39)	(4.37)	(1.34)	(2.54)	(4.68)
5	-0.092	-211.54	-48.89	-3.91	-9.46	8.82
	(0.006)	(11.78)	(4.33)	(1.38)	(2.56)	(4.82)
6	-0.056	-171.48	-48.62	-7.95	-15.97	-0.26
	(0.005)	(11.28)	(4.27)	(1.37)	(2.60)	(4.81)
7	-0.039	-155.65	-43.81	-10.41	-14.29	-2.03
	(0.005)	(10.96)	(4.15)	(1.37)	(2.66)	(4.92)
8	-0.040	-152.18	-37.60	-6.35	-17.09	-2.65
	(0.005)	(10.77)	(4.09)	(1.38)	(2.64)	(4.96)
9	-0.034	-132.64	-48.45	-9.45	-6.19	8.99
	(0.004)	(10.41)	(4.10)	(1.35)	(2.77)	(5.33)
10	-0.032	-128.82	-44.71	-9.84	-11.33	-2.54
	(0.004)	(10.25)	(4.12)	(1.39)	(2.76)	(5.19)
11	-0.030	-148.78	-44.15	-9.25	-9.45	4.83
	(0.004)	(10.39)	(4.07)	(1.37)	(2.82)	(5.54)
12	-0.031	-132.00	-29.39	-2.57	8.63	40.05
	(0.004)	(10.00)	(3.95)	(1.38)	(2.83)	(5.96)
13	-0.027	-126.72	-47.74	-10.05	-5.82	20.95
	(0.004)	(10.08)	(4.00)	(1.39)	(2.85)	(5.71)
14	-0.031	-106.32	-22.19	-1.21	9.26	38.51
	(0.004)	(9.80)	(3.89)	(1.37)	(2.83)	(5.89)
15	-0.026	-112.39	-35.61	-8.61	-2.56	22.23
	(0.004)	(9.90)	(3.90)	(1.39)	(2.91)	(5.97)
16	-0.030	-120.51	-25.37	-1.73	7.82	32.18
	(0.004)	(9.92)	(3.85)	(1.37)	(2.88)	(5.79)
17	-0.028	-107.93	-32.19	-5.83	0.32	29.12
	(0.004)	(9.86)	(3.97)	(1.39)	(2.91)	(5.97)
18	-0.026	-82.55	-21.36	-0.26	13.56	40.63
	(0.004)	(9.45)	(3.91)	(1.40)	(2.99)	(6.04)
19	-0.025	-81.72	-34.15	-8.05	-6.44	17.68
	(0.004)	(9.75)	(4.10)	(1.45)	(3.03)	(6.03)
20	-0.019	-102.63	-27.50	-3.28	0.37	31.91
	(0.004)	(10.36)	(4.16)	(1.49)	(3.10)	(6.28)
Baseline (pre-disp.) quantile of displaced workers	--	418	480	525	580	649

Notes: Column (1) shows estimated displacement effects on the probability of working a positive number of hours in a given quarter, based on estimates of equation (1). Columns (2)–(6) show estimated displacement effects on unconditional hours quantiles, obtained using the re-centered influence function approach (Firpo, Fortin, and Lemieux 2009). Standard errors clustered by worker are shown in parentheses. The estimates are based on a sample of 811,141 worker-quarter observations of 15,980 workers.

Source: Authors' calculations using Washington administrative wage and claims records. See section 4.2 of the text for further discussion.

Appendix Table A8
Estimated displacement effects on log earnings, log hours, log wage rates: full losses and losses due to employer fixed effects (ψ), UI claimant sample

Quarter relative to displacement	(1) Log earnings	(2)	(3) Log hours	(4)	(5) Log hours wage rate	(6)
	full loss	ψ effect	full loss	ψ effect	full loss	ψ effect
0	-0.40***	0.00**	-0.47***	0.00***	0.08***	-0.00
	(0.02)	(0.00)	(0.02)	(0.00)	(0.01)	(0.00)
1	-0.55***	-0.03***	-0.42***	-0.02***	-0.13***	-0.01***
	(0.02)	(0.01)	(0.02)	(0.00)	(0.01)	(0.00)
2	-0.44***	-0.03***	-0.29***	-0.02***	-0.17***	-0.02***
	(0.02)	(0.00)	(0.02)	(0.00)	(0.01)	(0.00)
3	-0.35***	-0.03***	-0.23***	-0.01***	-0.13***	-0.01***
	(0.02)	(0.00)	(0.02)	(0.00)	(0.01)	(0.00)
4	-0.36***	-0.03***	-0.24***	-0.01***	-0.13***	-0.02***
	(0.02)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
5	-0.30***	-0.03***	-0.14***	-0.01***	-0.16***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
6	-0.26***	-0.02***	-0.12***	-0.01***	-0.13***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
7	-0.27***	-0.02***	-0.13***	-0.01***	-0.13***	-0.01***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
8	-0.26***	-0.02***	-0.12***	-0.01**	-0.14***	-0.01***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
9	-0.25***	-0.02***	-0.11***	-0.01**	-0.13***	-0.01***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
10	-0.20***	-0.02***	-0.11***	-0.01*	-0.10***	-0.01***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
11	-0.24***	-0.01***	-0.11***	0.00	-0.12***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
12	-0.20***	-0.01**	-0.06***	0.01**	-0.14***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
13	-0.21***	-0.01***	-0.08***	0.01*	-0.13***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
14	-0.15***	-0.01**	-0.04***	0.01**	-0.11***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
15	-0.19***	-0.01*	-0.06***	0.01***	-0.11***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
16	-0.18***	-0.01**	-0.06***	0.01***	-0.12***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
17	-0.19***	-0.01**	-0.07***	0.01**	-0.12***	-0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
18	-0.14***	-0.01***	-0.02**	0.00	-0.11***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)
19	-0.17***	-0.02***	-0.05***	0.00	-0.12***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)
20	-0.17***	-0.02***	-0.05***	0.00	-0.11***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)

Number of worker-quarter observations	808,058	807,423	804,437	807,423	804,429	807,423
Number of workers	15,980	15,980	15,980	15,980	15,980	15,980
R^2	0.086	0.027	0.056	0.020	0.080	0.027

Notes: Columns (1), (3), and (5) show the coefficients (and standard errors clustered by worker) underlying in Figures 2, 3, and 5 in the main text. These are estimated δ_ks from equation (1) with the log of earnings, log of hours, and log of the wage rate from the primary employer as the dependent variables. Columns (2), (4), and (6) show the coefficients (and standard errors clustered by worker) underlying Figure 6. These are estimated δ_ks from equation (3) with employer fixed effects (ψ_{ijt}) for log of earnings, log of hours, and log of the wage rate from the primary employer [estimated by equation (2)] as the dependent variables.
Source: Authors' calculations using Washington administrative wage and claims records. See sections 3, 4, and 5.1 of the text for details.

Appendix B: Estimation of employer fixed effects for earnings, hours, and wage rates

This appendix describes estimation of the AKM employer fixed effects for earnings, hours, and hourly wages used in the main text. Raw data for the analysis come from quarterly administrative earnings records of Washington State. The records available to us provide information on the earnings and work hours of virtually all workers employed in Washington during 2002–2014,[5] as well as information on all UI-covered employers in the state.[6] A record appears for each employer-worker-quarter combination, so a worker has as many earnings records as he or she has employers in a given quarter. Each record includes a year-quarter indicator; the ID and NAICS industry code of the reporting employer; and the worker ID, earnings, and work hours of the worker with that employer in the specified quarter. The availability of both quarterly earnings and work hours allows us to calculate the hourly wage rate by quarter, and the availability of quarterly hours for each employer allows us to include both full-time and part-time jobs in the analysis.

[5] Exemptions from coverage are limited to the self-employed, including outside sales workers paid solely by commission and independent contractors meeting exemption tests specified in Washington's UI law (Revised Code of Washington, Title 50). Nonprofit religious organizations are also exempt.

[6] The employer is the entity from which the state collects UI payroll taxes and to which the state "charges" UI benefits (for the purpose of experience rating the UI payroll tax). Typically, the employer is the set of establishments operating in Washington under a single owner, so for a company operating entirely in Washington (with a single or multiple addresses) the employer is a firm, and for a company with one address in Washington, the employer is also an establishment.

Appendix B.1 Construction of the analysis sample

We use the raw administrative records to construct a linked employer-employee panel similar to a procedure developed by Sorkin (2018). First, for each quarter, we identify each worker's primary employer, defined as the employer from whom the worker earned the largest share of his/her earnings in that quarter.[7] We then define an employment spell as a series of at least five consecutive quarters during which a worker has earnings from the same primary employer. For each of these spells, we drop the first quarter (to avoid making inferences about earnings and hours based on a partial quarter of employment) and the last two quarters (to avoid making inferences based on earnings and hours in the quarter before a job loss and the quarter of a job loss).

We next annualize the remaining quarterly data within each calendar year, conditional on the calendar year including at least two consecutive quarters of earnings from the same primary employer. Earnings are defined as annualized earnings in a given year with the primary employer, and similarly for hours and wage rates.

Appendix Figure B1 illustrates the process and gives some examples, described in the figure notes. Ultimately, the unit of observation is the worker-year, with a focus on the primary employer in a year.[8]

We impose several restrictions on the sample, dropping the following:

- workers with more than 9 employers in a year (this affects 1 percent of the sample)

[7] In most cases, a worker has only one employer during the quarter, but multiple employers appear for about 27 percent of the worker-quarter observations.

[8] By removing the first quarter and the last two quarters of any worker-primary-employer spell and by including at least two consecutive quarters of earnings from the same primary employer in a calendar year, we lose about 27 percent of all worker-primary-employer spells. If we only remove the first quarter and the last two quarters of any worker-primary-employer spell (without requiring at least two consecutive quarters of earnings from the same primary employer in a calendar year), we lose about 23 percent of all worker-primary-employer spells.

- workers with annual earnings less than $2,850 (in 2005 dollars) and workers with calculated hourly wage rates ≤ $2.00/hour (in 2005 dollars) (Sorkin 2018; Card, Heining, and Kline 2013)
- workers who worked fewer than 400 hours in the year
- workers who worked more than 4,800 hours in the year
- employers with fewer than 5 employees in the year (Song, Price, Guvenen, Bloom, and von Wachter 2015)
- all displaced workers and all non-displaced comparison workers (as defined in section 2.1 of the main text)

The last restriction is imposed because including displaced workers and the non-displaced comparison group in estimating the AKM model could create a mechanical relationship between the employer fixed effects and displaced workers' earnings, hours, and wage rate losses, potentially overstating the role of employer fixed effects.

The first column of Appendix Table B1 ("Full annualized panel") shows summary statistics for the annualized linked employer-employee panel—that is, after processing the quarterly records as illustrated in Appendix Figure B1 and imposing the sample restrictions described above.

The employer effects are identified only within the "connected set" of employers that are linked by worker transitions between those employers, so the AKM estimation is necessarily restricted to the largest connected set of employers. This consists of 64 percent of employers in the full annualized panel, 79 percent of workers in the panel, and 90 percent of worker-year observations in the panel.

The second column of Appendix Table B1 shows descriptive statistics for the largest connected set. Because identification of employer fixed effects comes from workers moving between primary employers, it is important to know how much mobility there is in the sample. The table shows that the largest connected set includes about 3.5 million unique workers, and about 42 percent of those workers changed primary employer at least once during 2002–2014. The question is whether the extent of mobility in this sample is adequate for AKM to be an unbiased estimator of employer fixed effects, or if instead "limited mobility" bias is likely to be a problem (Andrews et al. 2012).[9]

Two factors suggest that limited mobility is unlikely to pose a problem in the Washington data. First, the average number of movers per employer in sample we use to estimate the AKM model is about 10. (For employers of the displaced workers, the average number of movers is 211). The analysis in Andrews et al. (2012) suggests that limited mobility bias is unlikely to be a problem with an average of more than 6 movers per employer.

Second, the rate of mobility in the Washington data appears quite high compared with the German data used by Card, Heining, and Kline (CHK) (2013), Fackler, Mueller, and Stegmaier (2017), and Schmieder, von Wachter, and Heining (2018). We can compute a measure of mobility in the German data using data reported in CHK, specifically by calculating the ratio of total moves in their event study analysis to the number of person-year or person observations. CHK report that there were 3,002,557 moves during the 2002–2009 interval (calculated from Appendix Table A.3 in CHK). In the same interval, there were 90,615,841 person-year

[9] Limited mobility bias is likely here are a limited number of job changers used to identify the AKM employer effect. In the AKM model, limited mobility bias appears as a small or negative correlation between worker and employer effects in variance decompositions, even when the "true" correlation is positive. Finding negative sorting of workers to employers in terms of wages/earnings is typically considered to be misleading.

observations and 15,834,602 persons (Table 3 in CHK). Dividing the number of moves by person-years (persons) gives a mobility rate of 0.03 (0.19).

In the Washington data there are 2,220,454 moves and 22,941,274 person-years and 3,508,811 persons (Appendix Table B1). Dividing the number of moves by person-years (persons) gives a mobility rate of 0.097 (0.63). Hence, the mobility rates in the Washington sample we use to estimate the AKM model appear to be relatively high.

Appendix B.2 Estimation and variance decompositions

We estimate the AKM model [equation (2) in the main text] using the linked employer-employee panel for each of the three outcomes: log earnings, log hours worked, and log wage rates. Appendix Table B2 displays the resulting variance decompositions. The variance of each outcome is decomposed into five components: one each for worker effects, employer effects, year effects, the covariance between worker and employer effects (sorting of workers and employers), and a residual. (To conserve space, we do not show the worker-year or employer-year covariances. Together, these two covariances explain about one percent of the variation in each outcome.) The numbers in italics below each variance-covariance term show the share of the total variance of each outcome attributable to that component.

Worker fixed effects explain a large share of the variation in all three outcomes: 52 percent of the variation in earnings, 45 percent of the variation in work hours, and 60 percent of the variation in hourly wage rates. This compares with worker fixed effects explaining 51 percent of the variation in earnings in Sorkin (2018) (see his Table 1, U.S., 2000–2008) and 51–61 percent of daily earnings in CHK (Table 3, Germany, 1985–2009).

Employer effects are also important: They explain about 20 percent of the variation in earnings, 35 percent of the variation in work hours, and 13 percent of the variation in hourly wage rates. This compares with employer fixed effects explaining about 14 percent of the variation in earnings in Sorkin (2018) and 18–21 percent in CHK (Table 3, Germany, 1985–2009).

The rightmost columns of Appendix Table B2 show adjusted-R^2s and RMSEs from a model in which each outcome variable is regressed on (i) an indicator for each worker-employer spell and (ii) year effects. CHK (2013, p. 990) suggest that the explanatory power of this model,

compared with the explanatory model of the AKM model, provides a test of the importance of idiosyncratic worker-employer matches, hence we refer to it as the "CHK match effects model" (to distinguish it from the match effects model described in Appendix A.10). The adjusted-R^2 from the AKM model for earnings is 0.872, whereas the adjusted-R^2 from the CHK match effects model for earnings is about 0.925.[10] Although the fit is somewhat better for the CHK match effects model, the roughly 5 percentage-point difference between the R^2s of the AKM and CHK match-effects models suggests that the AKM model specification of earnings as the sum of worker and employer fixed effects is not greatly off the mark.

[10]These estimates are similar to those in Sorkin (2018), who obtains an adjusted-R^2 of 0.86 for the AKM model of earnings, and an adjusted-R^2 of 0.92 for the CHK match effects model of earnings.

Appendix B.3 Event studies of inter-employer mobility

OLS estimation of the AKM model will be biased for the employer effects (ψ) if worker mobility among employers is endogenous, or correlated with time-varying components of the residual in equation (2). This problem would arise, for example, if workers moved to take advantage good specific employer-employee matches, or if workers developed specific human capital within a job over time.[11] To examine the importance of endogenous mobility, CHK developed an event study analysis of the movement of earnings when workers move among employers. If the AKM model is a correct description of earnings determination, then workers who move from low-ψ to high-ψ employers should on average see their pay rise, and conversely. Further, workers who move from low-ψ to high-ψ employers should receive (on average) pay increases equal and opposite those of workers who move from high-ψ to low-ψ employers. In contrast, the presence of specific employer-employee match effects would lead to average pay increases for workers moving in any direction, as they take advantage of opportunities for favorable specific matches.

Following CHK, we conduct event study analyses of how earnings, work hours, and wage rates change when workers move between employers of different types in the Washington linked employer-employee panel. For example, we can follow a group of workers who start with an employer whose fixed effect (ψ) is in the fourth quartile, and who then move to other employers. Some of these "destination" employers will have a high ψ, others will have a low ψ, and observing how workers' earnings, hours, and wage rates change with these moves provides information about employers' influence on earnings, hours, and wage rates.

[11] Card, Heining, and Kline (2013) and Card, Cardoso, Heining, and Kline (2018) provide clear discussions of the assumptions needed for unbiased estimation of employer fixed effects in the AKM model, with several examples of situations that do and do not violate those assumptions.

The procedure for constructing these event studies is as follows. For each outcome (earnings, hours, or wage rates) we classify employers into quartiles by their AKM-estimated employer effect (ψ). Next, for a given year t, we select workers in each ψ quartile who have been with the employer at least two years, change employers (i.e., are observed with a different primary employer in year t+1), and remain with the subsequent employer for at least two years. Finally, we calculate the average outcome before and after the move for each possible type of interquartile move (1→1, 1→2, ..., 4→3, and 4→4).

Appendix Figure B2 shows the results for eight of interquartile transitions (4→4, 4→3, 4→3, 4→1 1→4, 1→3, 1→2, and 1→1) for log earnings. Appendix Figures B3 and B4 show same transitions for log work hours and log wage rates. Appendix Table B3 displays the data underlying these figures.

We note two main points about Appendix Figure B2. First, workers who move from lower-ψ to higher-ψ employers tend to improve their earnings, and conversely. For example, workers who start with a low-ψ (quartile 1) employer and move to a high-ψ (quartile 4) employer experience a 70 log point increase in their earnings. (This 1→4 change falls to 60 log points when adjusted by the 1→1 within-quartile change, which is 10 log points—see the "Adjusted change from year –2 to year 1" column in Appendix Table B3.) Conversely, workers who start with a high-ψ (quartile 4) employer and move to a low-ψ (quartile 1) employer experience a 54 log point decrease in their earnings (63 log points if adjusted by the 4→4 within-quartile change, which is 9 log points). Consistent with the AKM model, the pay of workers who move from low-ψ to high-ψ employers increases on average, and conversely. Appendix Figures B3 and B4 show similar patterns.

Second, the approximate symmetry of gains and losses suggests that idiosyncratic match effects are not of great importance (CHK, p. 990). If employer-employee match effects were important, we would observe average pay increases for workers moving in any direction, but this is not the case. The symmetry of earnings changes for workers moving from low-ψ to high-ψ employers and those moving from high-ψ to low-ψ employers is consistent with the specification of the AKM model, with its additive worker and employer effects. For the Washington labor market overall, the AKM model appears to be a reasonable fit.

Appendix B.4 Estimating the AKM model using random subsamples of employers

Because the available data come from a single state, any worker who moves out of Washington and takes a job in another state cannot be observed. To examine the extent to which this attrition affects the estimated AKM employer fixed effects, we have re-estimated the AKM model after dropping random subsamples of 30 percent and 50 percent of employers from the AKM sample described in Appendix B.1. The idea is to approximate a situation where Washington workers move to out-of-state employers who cannot be observed in the Washington data.

The resulting employer fixed effects, presented in Appendix Figures B5 and B6, correlate very strongly with those obtained in the original full AKM sample analysis, suggesting that interstate migration does not bias the AKM results to a large extent.

Appendix Table B1
Summary statistics for the overall sample and the largest connected set (AKM dataset)

	Full annualized panel	Largest connected set
Number of worker/year observations	25,578,007	22,941,274
Number of unique workers	4,450,785	3,508,811
Number of unique employers	341,553	218,593
Number of unique movers	1,546,094	1,463,030
Number of mover/year observations	2,394,145	2,220,454
Log earnings (mean)	10.321	10.432
Log hours (mean)	7.338	7.453
Log hourly wage rate (mean)	3.063	3.052

Source: Authors' tabulations of Washington administrative wage records, 2002–2014. See Appendix section B.1.

Appendix Table B2
Variance decompositions of log earnings, log hours, and log hourly wage rates, Washington, 2002–2014
(variance shares accounted for by each component in italics)

	Variance of outcome and decomposition into components						AKM model fit		CHK match effects model fit	
Outcome	Total variance	Worker FEs (α)	Employer FEs (ψ)	Year FEs (θ)	2cov(α,ψ)	Residual	Adj. R^2	RMSE	Adj. R^2	RMSE
Log earnings	0.596	0.309	0.123	0.004	0.101	0.064	0.872	0.253	0.925	0.211
		0.519	*0.207*	*0.006*	*0.169*	*0.107*				
Log hours	0.129	0.058	0.045	0.000	–0.013	0.039	0.638	0.197	0.754	0.178
		0.449	*0.352*	*0.001*	*–0.104*	*0.303*				
Log hourly wage rate	0.411	0.247	0.053	0.022	0.065	0.040	0.885	0.199	0.932	0.167
		0.601	*0.128*	*0.054*	*0.159*	*0.096*				

Source: Authors' tabulations of Washington administrative wage records, 2002–2014.
Notes: The decompositions include covariances between worker and employer fixed effects and year fixed effects. Because these covariances explain only about 1 percent of the variation, they are omitted from the table. The CHK match effects model is estimated by regressing each outcome variable on worker-employer indicators and year indicators. See Appendix section B.2.

Appendix Table B3
Mean outcomes, classified by quartile of employer fixed effect

Panel A: Mean log earnings of movers, classified by quartile of employer earnings fixed effect at origin (year = –1) and destination (year = 0) employer

Origin/destination quartile	Year –2	Year –1	Year 0	Year 1	Change from year –2 to year 1	Adjusted change from year –2 to year 1[a]	Number of observations
1 to 1	9.79	9.79	9.88	9.89	0.10	0.00	247,950
1 to 2	9.83	9.83	10.12	10.14	0.31	0.21	120,636
1 to 3	9.80	9.81	10.27	10.30	0.50	0.40	74,936
1 to 4	9.88	9.89	10.54	10.58	0.70	0.60	38,488
2 to 1	10.16	10.13	10.03	10.03	–0.12	–0.18	80,566
2 to 2	10.29	10.28	10.35	10.35	0.06	0.00	173,078
2 to 3	10.36	10.35	10.54	10.55	0.19	0.13	116,916
2 to 4	10.39	10.39	10.75	10.78	0.38	0.33	57,176
3 to 1	10.36	10.32	10.02	10.02	–0.34	–0.40	29,168
3 to 2	10.52	10.50	10.46	10.46	–0.07	–0.12	84,368
3 to 3	10.65	10.64	10.70	10.71	0.06	0.00	234,702
3 to 4	10.73	10.73	10.92	10.94	0.21	0.15	122,092
4 to 1	10.72	10.70	10.18	10.18	–0.54	–0.63	13,102
4 to 2	10.77	10.74	10.51	10.51	–0.25	–0.34	27,982
4 to 3	10.87	10.86	10.81	10.81	–0.06	–0.15	84,974
4 to 4	11.15	11.15	11.21	11.24	0.09	0.00	313,108
							1,819,242

Panel B: Mean log hours of movers, classified by quartile of employer hours fixed effect at origin (year = –1) and destination (year = 0) employer

Origin/destination quartile	Year –2	Year –1	Year 0	Year 1	Change from year –2 to year 1	Adjusted change from year –2 to year 1[a]	Number of observations
1 to 1	7.24	7.22	7.27	7.26	0.02	0.00	221,266
1 to 2	7.27	7.24	7.49	7.47	0.20	0.18	124,596
1 to 3	7.22	7.18	7.56	7.55	0.33	0.32	69,170
1 to 4	7.21	7.17	7.65	7.64	0.43	0.42	55,296
2 to 1	7.45	7.41	7.29	7.28	–0.18	–0.17	78,030
2 to 2	7.51	7.48	7.52	7.50	–0.01	0.00	169,094
2 to 3	7.50	7.47	7.58	7.57	0.07	0.08	142,100
2 to 4	7.49	7.46	7.66	7.65	0.16	0.16	83,628
3 to 1	7.54	7.50	7.25	7.23	–0.31	–0.31	32,736
3 to 2	7.57	7.54	7.51	7.49	–0.09	–0.08	90,480
3 to 3	7.58	7.55	7.58	7.57	–0.01	0.00	189,088
3 to 4	7.59	7.57	7.66	7.65	0.05	0.06	144,280
4 to 1	7.65	7.61	7.21	7.20	–0.45	–0.44	21,302
4 to 2	7.66	7.63	7.50	7.48	–0.18	–0.17	47,296
4 to 3	7.65	7.63	7.60	7.58	-0.07	–0.07	115,634
4 to 4	7.67	7.66	7.68	7.67	0.00	0.00	235,246
							1,819,242

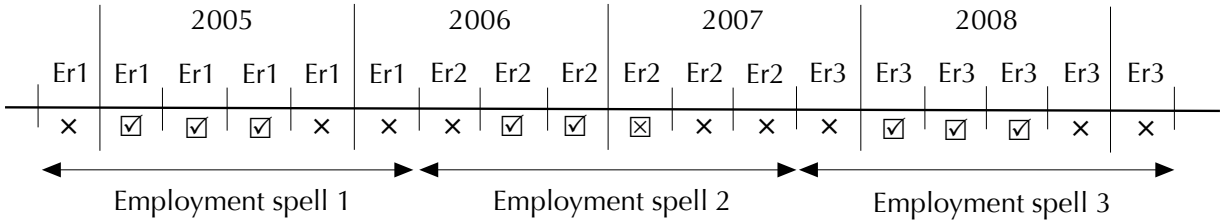
Note: a. The adjusted change is the change from year –2 to year 1, minus the within-quartile change from year –2 to year 1.

Panel C: Mean log hourly wage rate of movers, classified by quartile of AKM employer wage effects at origin (year = –1) and destination (year = 0) employer

Origin/destination quartile	Year –2	Year –1	Year 0	Year 1	Change from year –2 to year 1	Adjusted change from year –2 to year 1[a]	Number of observations
1 to 1	2.46	2.49	2.53	2.57	0.12	0.00	225,660
1 to 2	2.54	2.59	2.75	2.80	0.26	0.15	121,060
1 to 3	2.57	2.64	2.90	2.96	0.39	0.27	82,656
1 to 4	2.65	2.71	3.17	3.23	0.59	0.47	45,184
2 to 1	2.72	2.76	2.69	2.73	0.01	–0.12	97,952
2 to 2	2.86	2.90	2.95	2.99	0.13	0.00	164,396
2 to 3	2.91	2.96	3.09	3.14	0.23	0.10	127,162
2 to 4	2.93	2.98	3.27	3.33	0.40	0.27	61,112
3 to 1	2.91	2.94	2.75	2.79	–0.13	–0.27	44,052
3 to 2	3.03	3.07	3.04	3.07	0.04	–0.10	100,114
3 to 3	3.12	3.17	3.22	3.27	0.14	0.00	195,376
3 to 4	3.22	3.27	3.45	3.50	0.29	0.14	121,480
4 to 1	3.17	3.21	2.78	2.82	–0.35	–0.51	17,238
4 to 2	3.29	3.33	3.12	3.16	–0.14	–0.30	40,524
4 to 3	3.37	3.41	3.33	3.37	0.00	–0.16	95,154
4 to 4	3.59	3.64	3.68	3.75	0.16	0.00	280,122
							1,819,242

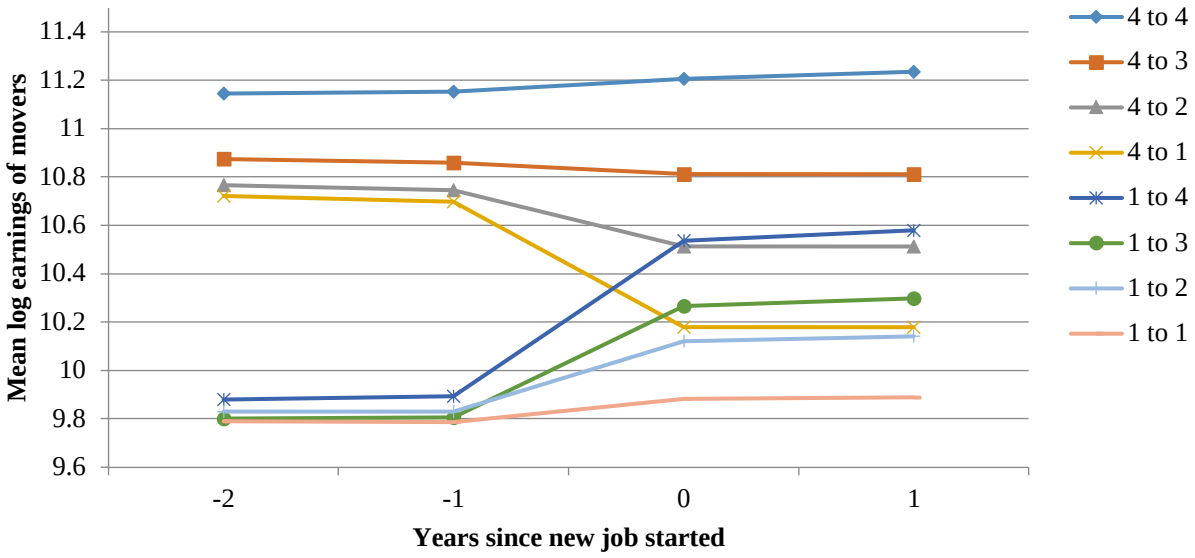
Note: a. The adjusted change is the change from year –2 to year 1, minus the within-quartile change from year –2 to year 1.

Appendix Figure B1
Construction of the analysis sample for the AKM dataset

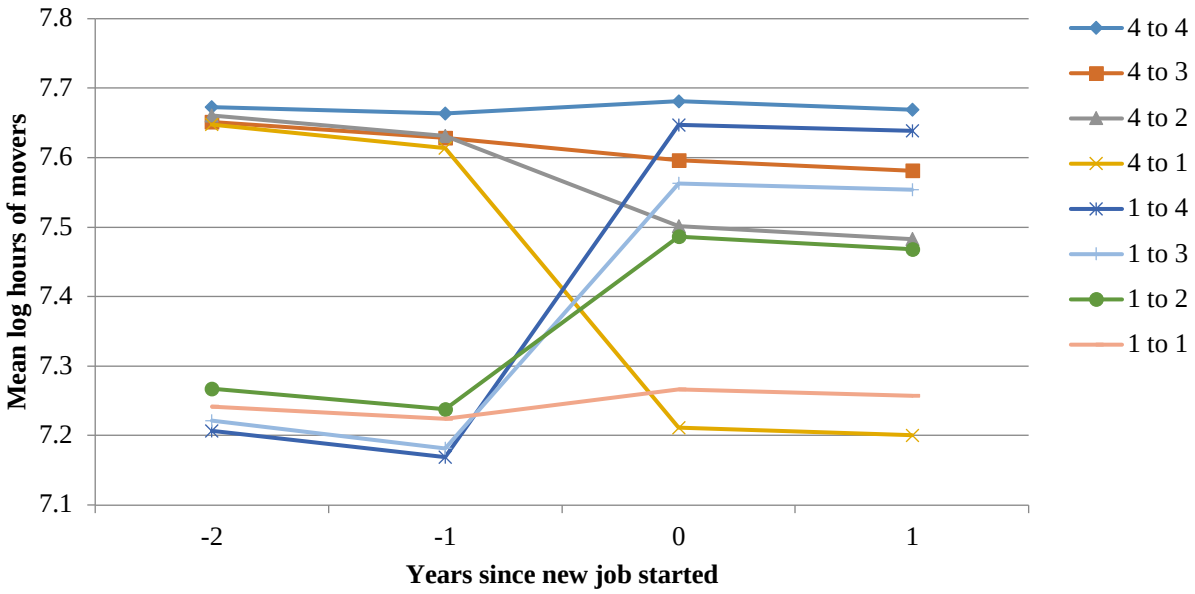


Notes: The figure shows three hypothetical employment spells with three different employers (Er1, Er2, and Er3), each of which has the minimum five quarters required to be included in the analysis sample. The first quarter and last two quarters of each employment spell (denoted by ×) are dropped from the analysis, and outcomes from the remaining quarters are then annualized for each calendar year, conditional on the calendar year including at least two consecutive quarters of earnings from the same primary employer. For example, outcomes for 2005 (Employment spell 1) and 2008 (Employment spell 3) are obtained by averaging the outcomes for the first, second, and third quarters of 2005 (or 2008) and multiplying by four. (The quarters used in the calculations are denoted by ☑.) Outcomes for 2006 (Employment spell 2) are obtained by averaging the outcomes for the third and fourth quarters of 2006 and multiplying by four. Outcomes for 2007 (part of Employment spell 2) are excluded because 2007 does not include two consecutive quarters that can be used under the selection criteria (that is, after excluding the first quarter and last two quarters of each employment spell). As a result, the data from 2007:I (denoted by ☒) are not used.

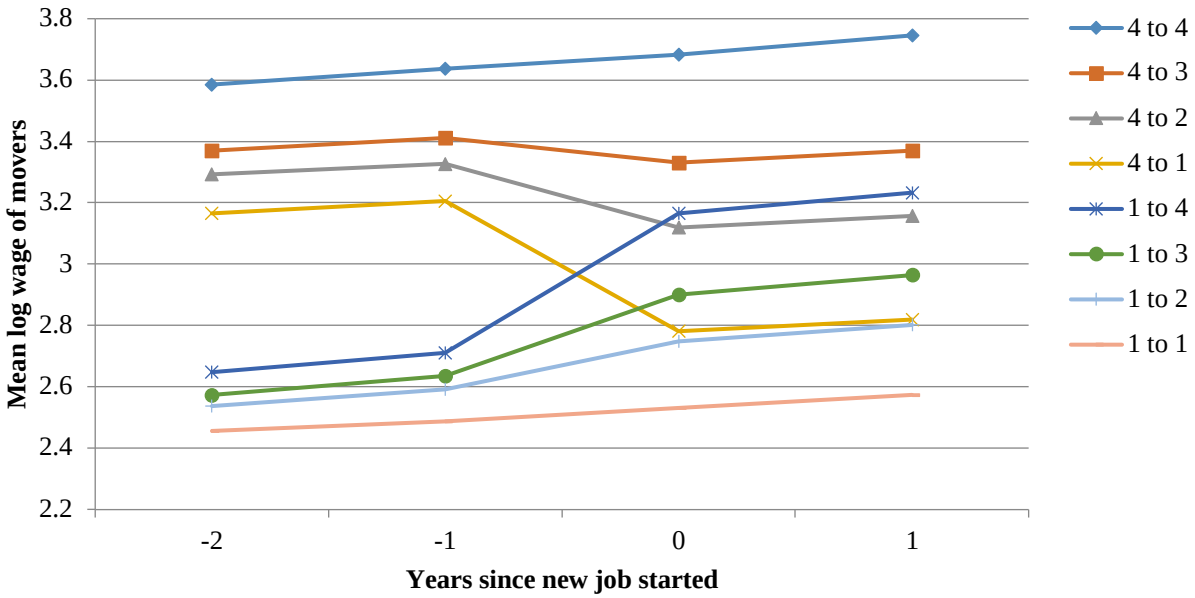
Appendix Figure B2
Mean log earnings of movers, classified by quartile of AKM employer earnings effects (ψ) at origin (year = –1) and destination (year = 0) employer



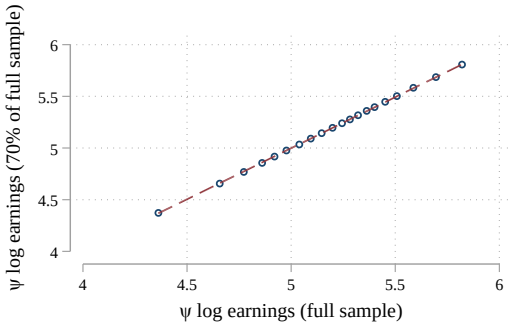
Appendix Figure B3
Mean log hours of movers, classified by quartile of AKM employer hours effects (ψ) at origin (year = –1) and destination (year = 0) employer



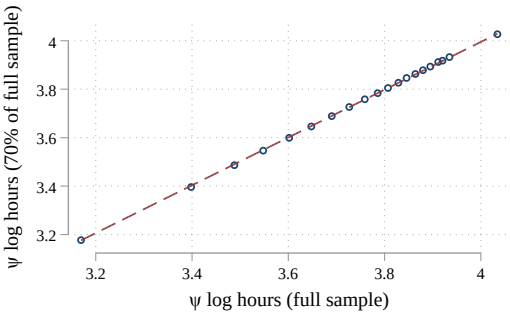
Appendix Figure B4
Mean log hourly wage rates of movers, classified by quartile of AKM employer wage rate effects (ψ) at origin (year = –1) and destination (year = 0) employer



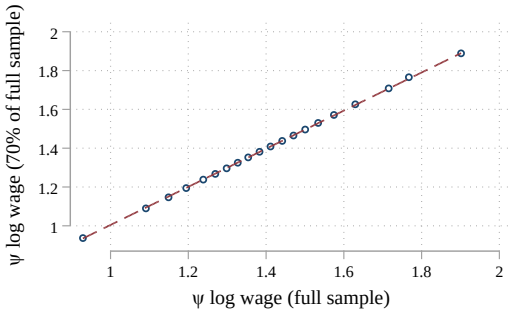
Appendix Figure B5
Correlation of estimated employer fixed effects for the full AKM sample and a random 70 percent sample of employers



Correlation = 0.9815

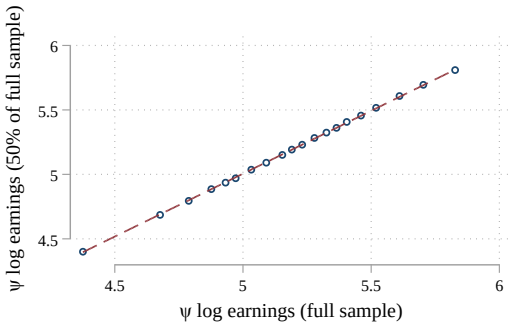


Correlation = 0.9697

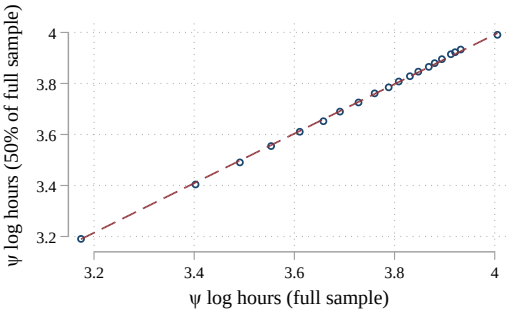


Correlation = 0.9733

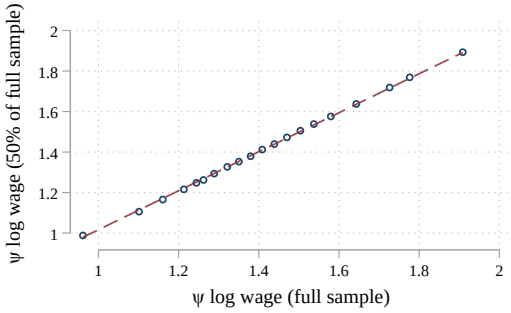
Appendix Figure B6
Correlation of estimated employer fixed effects for the full AKM sample and a random 50 percent sample of employers



Correlation = 0.9625



Correlation = 0.9381



Correlation = 0.9459

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