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**Working Paper**

## Job displacement costs of phasing out coal

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22/37

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Juan-Pablo Rud

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## Abstract

The reduction of carbon emissions will require a rapid phasing out of coal and the displacement of millions of coal miners. How much could this energy transition cost mining workers? We use the dramatic collapse of the UK coal industry to estimate the long-term impact on displaced miners. We find evidence of substantial losses: wages fall by 40% and earnings fall by 80% to 90% one year after job loss. The losses are persistent and remain significantly depressed fifteen years later, amounting to present discounted value earnings losses of between four and six times the miners pre-displacement earnings. (JEL J30, J63, J64, O4)

We intend to support communities and regions that are particularly vulnerable to the economic, employment and social effects of a global transition away from carbon-intensive activity

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*Just Transition Declaration, 04.11.2021*

*U.N. climate change conference COP26*

A well-established literature finds that displaced workers suffer substantive earning losses that persist several years after losing their job ([Jacobson et al., 1993](#); [Stevens, 1997](#); [Couch and Placzek, 2010](#); [Davis and von Wachter, 2012](#); [Bertheau et al., 2022](#)).<sup>1</sup> These findings raise concerns regarding

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<sup>1</sup>Displacements also have been shown to impact health ([Sullivan and von Wachter, 2009](#); [Lindo, 2011](#); [Schaller and Stevens, 2015](#)), schooling ([Rege et al., 2011](#)), fertility ([Huttenen and Kellokumpu, 2016](#)), divorce ([Charles and](#)

the future of millions of coal miners who will likely be displaced and forced to switch sectors if plans to phase out coal to reduce carbon emissions are implemented due to climate change concerns (United Nations, 2022; Ruppert Bulmer et al., 2021).<sup>2</sup> How much will this energy transition cost to mining workers? Answering this question is important to account for the economic losses of phasing out coal and to inform policies aimed at mitigating its social costs.

The existing evidence on job displacement costs is, however, unsuitable to quantitatively answer this question. The majority of the existing studies rely on mass layoff events using samples representative of the whole workforce to estimate the costs of job displacement. These estimates of average earnings losses are likely to be well below the costs of job loss for a coal miner who faces the complete phase-out of an industry. The collapse of an entire sector will force sector reallocation. Since coal mining is a highly specialized occupation (Samuel, 2016), this specificity of human capital may reduce miners' ability to transfer their skills, in particular if they are forced to switch occupations.<sup>3</sup> Moreover, most coal miners are employed in remote and rural areas where mining is often the main employer. This feature reduces local economies capacity to absorb workers after a mine closure and, due to the need to emigrate, may increase workers' job searching costs and non-employment durations.

The contribution of this paper is to provide estimates of job displacement costs during a well known episode of sector collapse specific to coal miners. We study the dissolution of the UK coal industry that accelerated in mid-1980s under Margaret Thatcher. This dissolution was comprehensive and fast: in just over a decade, the majority of coal mines closed and more than 200,000 miners (almost 90 percent of the industry's workforce) lost their job (Glyn and Machin, 1997; Aragon et al., 2018) (see Figure 1). This setting is one of the few documented experiences of a large and systematic displacement of miners, and thus offers an opportunity to learn about the possible long-term impact of coal phase-out.

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Stephens, 2012; Eliason, 2012) and retirement decisions (Chan and Stevens, 1999, 2001; Merkurieva, 2019). Losses also vary with the business cycle (Davis and von Wachter, 2012; Gulyas and Pytka, 2020; Schmieder et al., 2022). A related literature also studies the underlying causes of the losses in earnings (Krolikowski, 2017b; Jung and Kuhn, 2018; Burdett et al., 2020; Lachowska et al., 2020; Gulyas and Pytka, 2020; Raposo et al., 2021; Jarosch, 2021; Simmons, 2021; Huckfeldt, 2022; Braxton and Taska, 2022; Leenders, 2022)

<sup>2</sup>See Appendix for our back-of-the-envelope calculation of the aggregate number of active coal miners adding up to around 5.4 million.

<sup>3</sup>Neal (1995), Huckfeldt (2022) and Braxton and Taska (2022) find that those who switch sectors and occupations following job loss fair worse than those who do not.

Our empirical analysis uses data from the UK New Earnings Panel Survey. This survey collects earnings information from a representative sample of individuals from 1975 to the present. The richness of the data allow us to construct a longitudinal dataset tracking more than 2,000 displaced coal miners many years before and after job separation. We estimate the impact of the average worker's final displacement from a mine on wages and earnings using a panel data model with time and individual fixed effects commonly used in the literature. This estimator compares the evolution of earnings of displaced workers relative to a group of observationally similar, non-displaced, workers. This control group is constructed by matching coal miners to blue-collar manufacturing workers with similar pre-displacement characteristics. We provide several variations to the definition of the treatment and control groups and show that our results remain robust and quantitatively very similar.

We find evidence of large and persistent earnings losses. Wages for those in work drop by around 40% during the first years after job loss, and remain around 20% fifteen years later. Overall earnings fall by 80% to 90% in the year after displacement and remain depressed by 20% to 30% fifteen years later. Over the fifteen year period, present discounted earnings losses amount to between 4 and 6 times the miners pre-displacement earnings.

Our findings are qualitatively similar to other studies on job displacement. However, the magnitudes are substantially larger. For instance, [Couch and Placzek \(2010\)](#) document more moderate earnings losses of 32-33% in the first year and 13-15% after six years, while [Davis and von Wachter \(2012\)](#) estimate cumulative losses over a twenty year period of around 1.7 times pre-displacement earnings. The large and persistent earning losses are consistent with coal miners being particularly vulnerable to job displacement, perhaps due to the low transferability of occupation-specific skills or lower labor mobility. Assuming that these conditions apply to coal miners in other contexts, our results suggest that the phasing out of coal could bring substantial disruptions to miners, their families and mining communities. Active labor market policies ([Card et al., 2018](#); [Van Den Berg and Vikström, 2022](#)) are likely to be particularly important in this context.

The remainder of the paper proceeds as follows. In Section [I](#) we briefly discuss the dissolution of the UK coal industry. In Section [II](#) we discuss the empirical strategy and Section [III](#) presents the results. We conclude in Section [IV](#).

# I BACKGROUND

Coal played a key role fuelling UK's industrialization process and was an important source of well-paid, manual, jobs. By the early 1980s, however, the industry had experienced a long, albeit gradual, decline and was reliant on government subsidies (NUM, 2021; Glyn, 1988). In 1985, after a year-long strike, the government started withdrawing its support and the mine closures accelerated.

The dissolution of the industry was comprehensive and fast (Glyn, 1988; Glyn and Machin, 1997; Aragon et al., 2018). In just two years, 1985 to 1986, one-third of coal mines closed. By 1994, when the industry was privatized, only 26 mines were operational out of more than 200 at the beginning of 1980s. By early 2000s, only a handful of mines remained. The closure of mines was mirrored by a massive displacement of coal miners. Between 1980 and 1994, more than 200,000 miners lost their jobs (see Figure 1). This amount represented a reduction of approximately 90 percent of the industry's workforce.

The socioeconomic impact of coal mine closures, especially at the community level, has been widely studied. These studies document severe and persistent negative impacts on employment and participation rates, population and living conditions in the affected mining communities (Beatty and Fothergill, 1996; Bennett et al., 2000; Beatty et al., 2007; Aragon et al., 2018).

There is also some evidence on the direct impact on miners. These studies confirm the deterioration of labor outcomes, albeit they do not estimate long-term earning losses due to job displacements. Moreover, they highlight the limited use of migration or changes in occupation as a response to job loss. Instead, many miners seem to have retired earlier or declared sick or permanently disabled, a phenomenon called "hidden unemployment". For instance, Fieldhouse and Hollywood (1999) find that in 1991, the employment rate of individuals identified as miners in 1981 was around 30%, much lower than the average rate of 50%. They also find that, consistent with hidden unemployment, a large fraction of former miners (around 50%) reported to be permanently sick or retired early. Hollywood (2002) documents that miners, especially the older and less educated, have been less likely to migrate relative to workers in other highly-specialized occupations, such as metal manufacturing. In general, most studies on the socioeconomic impact of the coal mine closures on the displaced miners conclude that there are few, *if any*, more striking

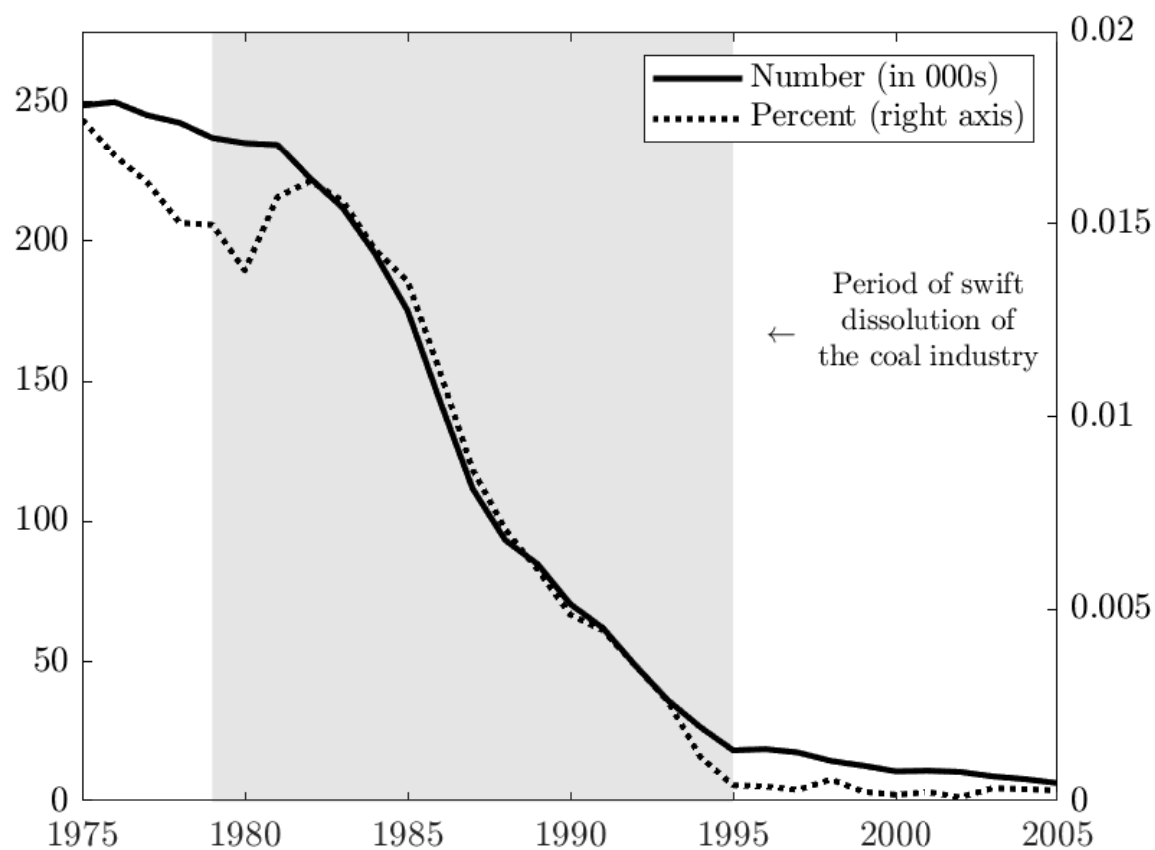


FIGURE 1: Coal mining employment in the UK 1975-2005

Source: The number employed is collected from [National Coal Board \(1970-1993\)](#) and used in [Aragon et al. \(2018\)](#). The percent shown on the right axis was calculated from the New Earnings Survey.

examples of chronic job loss in Western Europe, with nearly all the burden carried by a few local areas and a specific segment of the workforce - male, manual workers, as first documented in [Beatty and Fothergill \(1996\)](#).

There have been several policies aimed at fostering the economic recovery of former mining. These regeneration policies have included re-training of local workers, promotion of small and medium-sized business, and construction of local infrastructure, among others. However, their success has been limited and former mining communities remain among the poorest in the UK ([Guy, 1994](#); [Beatty et al., 2007](#)).

## II METHODS

### II.A DATA

**Data:** We use data from the 2017 New Earnings Panel Survey (Office for National Statistics, 2017).<sup>4</sup> This is a longitudinal survey that tracks cohorts of individuals from 1975 to the present and provides annual information on weekly earnings and hours worked. Throughout we deflate earnings to 2000 prices. Information is also provided on occupation, industry, gender, age, geographical administrative unit, and whether the wage was determined through a collective agreement. Individuals are tracked using their National Insurance number, a unique tax identifier which does not change over the lifetime of a worker. This feature allows us to track individuals even after unemployment spells, and across different employers and locations.

**Treatment:** Studies focusing on the identification of job displacements, typically define mass layoffs in situations in which firm's employment permanently declines by thirty or more percent over a short period of time such as for example in [Davis and von Wachter \(2012\)](#), [Flaaen et al. \(2019\)](#) and [Bertheau et al. \(2022\)](#). As discussed in the background section, the dissolution of the coal industry proceeded fairly quickly and was plausibly exogenous to the individual coal miner, implying selection is less of a concern. This allows us to study all separations during this period, which is distinguishing us from the previous literature focusing only on the proportion of layoffs

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<sup>4</sup>This data set was used to study the effect of minimum wages on wage dispersion and employment ([Machin and Manning, 1994](#)), the distribution of top earnings in the UK since WWII ([Atkinson and Voitchovsky, 2011](#)), as well as spatial differences in earnings and unemployment ([Blackaby and Manning, 1990](#)).



during mass layoffs. Note that the complete dissolution of the sector also allows us not to worry about mergers, takeovers, or changes in the identification number of firms. The dissolution of the coal sector was determined on the national level and brought to a conclusion 30 years later, even though 80% of the task was accomplished within a period of 10 years, by 1995.

**Displaced miners:** We follow the literature and choose for each year  $t$  all workers that work full time at a coal mine. From this group of miners we keep those who are between 25 and 55 years old, and those who were employed by the same firm for at least 2 consecutive years, in  $t$  and  $t - 1$ , before being laid-off between  $t$  and  $t + 1$ . We focus on the periods during which the coal industry collapses, and analyse displacements in the years between, and inclusive of, 1979 and 1995. Since we are interested in displacements associated with being subsequently unable to work in coal mining, we focus on a workers' final separation from a mine. This leaves us with 17 year specific cohorts and 2,152 miners at the time of displacement. Each cohort contains 20 years, 4 prior to displacement and 15 after. Let  $k = \{-4, 15\}$  represent these years where a displacement occurs between  $k = 0$  and  $k = 1$ . In alternative specifications we adjust the sample and analyse (i) miners working underground only (excluding white-collar workers) and (ii) displacements that occurred along with the closure of a mine at the county level (standard geographical administrative unit). Focusing on displacements that occurred along with the closure of a mine at the county level, as in (ii), allows us to test whether closures are driving our results.

The New Earnings Survey is based on a random sample of workers enrolled in the pay-as-you-earn (PAYE) scheme. The PAYE is a payroll-deduction system in which employers collect taxes and insurance payments from their employees' wages. This system does not include the self-employed, a data limitation which is shared by many other studies in the literature such as for example [Jacobson et al. \(1993\)](#), [Schmieder et al. \(2022\)](#) and [Bertheau et al. \(2022\)](#). These papers deal with this limitation in two distinct ways. On the one hand, periods without any observed labor earnings in the data are interpreted as zero individual earnings, such as in [Schmieder et al. \(2022\)](#) and [Bertheau et al. \(2022\)](#). Using the British Household Panel Survey and studying the costs of job loss in the UK, [Upward and Wright \(2017\)](#) find that reassigning earnings during periods of self-employment as zero makes very little difference to the estimated earnings losses. [Bertheau et al. \(2022\)](#) also find that a similar exercise using Swedish data results in only minor differences. While

these studies find the issue to be negligible, we are unable to say whether it is indeed negligible in our case. Thus, we complement our results with a similar approach to [Jacobson et al. \(1993\)](#), and only keep those individuals who experience positive earnings within four years of displacement. This latter approach provides a more conservative estimate of displacement costs by focusing on individuals who eventually return to work within a certain time frame.

**Control group:** To obtain a causal estimate of being displaced, we require a comparable control group of workers who did not experience job loss during the same year as the miners but followed the same pre-displacement employment and earnings path. Choosing a control group in this setting is a particular challenge by the very nature of the exercise - a group of miners who did not lose their job does not exist.

Our baseline approach is to match miners to blue collar manufacturing workers with the same two-digit occupation code using propensity score matching. In practice this involves estimating a probit or logit model with the dependent variable taking the value of 1 if they are in the treated group and 0 otherwise, and then matching treated and control workers with the closest predicted value without replacement.<sup>5</sup> We match on an array of observable characteristics: age, gender<sup>6</sup>, hours worked, full-time status, geographical administrative unit (County), whether the wage was determined by a collective agreement, as well as the workers pre-layoff weekly earnings and hours worked between  $k = -4$  and  $k = -1$  and employment levels between  $k = -4$  and  $k = -2$ . We do not require the comparison group to be employed during any year after displacement including the displacement year, i.e. for  $k > 0$ . Such a requirement could lead to systematic differences between displaced and control groups, and possible overestimation of the earnings losses ([Krolkowski, 2017a](#)).

In Table 1 we provide basic statistics for the main observable characteristics on which we match before displacement for  $k = -4$  and  $k = -1$ . In columns we show mean and standard deviations for three distinct groups: the treated, the individuals from our baseline matching as well as the individuals from the non-matched control group (blue collar manufacturing workers). In comparison to the non-matched sample we see that the displaced coal miners are special since they

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<sup>5</sup>We use the `psmatch2` function within STATA to perform the propensity score matching ([Leuven, 2003](#)).

<sup>6</sup>Females make up about 6% of the mining workers in our treatment group. We chose to keep the females in our preferred specification, but the results do not change by removing all females. See the Online Appendix.

	(1)	(2)	(3)
	Treated	Main control	No matching
$k = -4$			
Weekly Earnings	321.86 (160.12)	317.12 (207.92)	252.50 (190.60)
Employment	.921 (.270)	.907 (.291)	.806 (.395)
Age	39.35 (8.07)	39.26 (7.91)	38.11 (7.67)
Weekly Hours	37.21 (2.20)	37.88 (3.82)	37.63 (4.66)
Male	.947 (.225)	.913 (.288)	.764 (.425)
Overtime pay	25.10 (43.45)	24.89 (41.48)	14.82 (31.87)
$k = -1$			
Weekly Earnings	355.29 (148.93)	353.12 (199.20)	328.35 (31.87)
Employment	1.00 (0)	1.00 (0)	1.00 (0)
Age	40.73 (9.10)	40.75 (8.91)	39.67 (8.54)
Weekly Hours	37.11 (2.45)	37.37 (4.16)	37.55 (4.47)
Male	.942 (.236)	.913 (.288)	.764 (.426)
Overtime pay	32.02 (54.96)	27.29 (48.68)	18.28 (39.01)
N	2,152	2,152	379,904

TABLE 1: Observables of the treated group, matched control group and non-matched control group

Note: Standard deviations are shown in parentheses.

are more likely to be male, a bit older and have higher earnings. As expected, the matching greatly reduces these differences.

Despite being able to match on an array of observable characteristics, we complement our results by providing an alternative control group for comparison. We restrict the pool of workers from which we match to workers which are involved in the creation of primary metal products consisting of iron, aluminum and copper as well as their alloys.<sup>7</sup> Primary metal manufacturing plants traditionally employ male manual workers with sector specific skills which are difficult to reemploy anywhere else and which due to the nature of their activity are operating in spatially remote locations. To produce primary metal products, heat from a variety of fuels, most commonly coal, is used for smelting such that metal production plants are often located next to coal deposits to keep transportation costs of coal at a minimum (Michielsen, 2013). Since this control group is chosen from a subset of blue collar manufacturing workers, we are implicitly leaning less heavily on the propensity score matching routine relative to the baseline. The advantage to the approach is that this control group may be better suited to capture the dynamics of unobserved characteristics of the displaced miners, such as long-run trends in technological progress and structural transformation.

## II.B EMPIRICAL MODEL

Using the 17 stacked treatment and control cohorts we run a similar regression model as other studies in the job displacement literature (Jacobson et al., 1993; Couch and Placzek, 2010). In particular, we estimate the following panel data model with distributed lags:

$$y_{ik} = a_i + \gamma_k + \mathbf{x}'_{ik}\beta + \sum_{k=-3}^{15} \delta_k D_{ik} + u_{ik}, \quad (1)$$

where  $y_{ik}$  is the outcome for individual  $i$  at time  $k$ , such as earnings, wages, or employment status.  $a_i$  and  $\gamma_k$  are person and time fixed effects, respectively.  $\mathbf{x}_{ik}$  is a vector of observables (quartic in age).  $D_{ik}$  are dummies for year  $k$  and  $u_{ik}$  is the error term, which we cluster at the individual level.

The coefficients of interest are  $\delta_k$ . These coefficients provide an estimate of the impact of displacement,  $k$  years after separation. We normalize the continuous outcome variables (such as

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<sup>7</sup>The associated standard industrial classification codes that we chose are 311, 312, 313, 321, 322, 333 (before 1984), 2210, 2220, 2234, 2235, 2245, 2246, 2247 (after 1984).

earnings and wages) by dividing them by the individual’s pre-displacement average, i.e. for  $k < 0$ . Thus, we can interpret  $\delta_k$  as the percentage change relative to pre-displacement values. Similar to previous work, the identification assumption is that, conditional on the control variables, the evolution of the displaced miners’ outcomes would have followed a similar path as the comparison group’s, had they not been displaced.

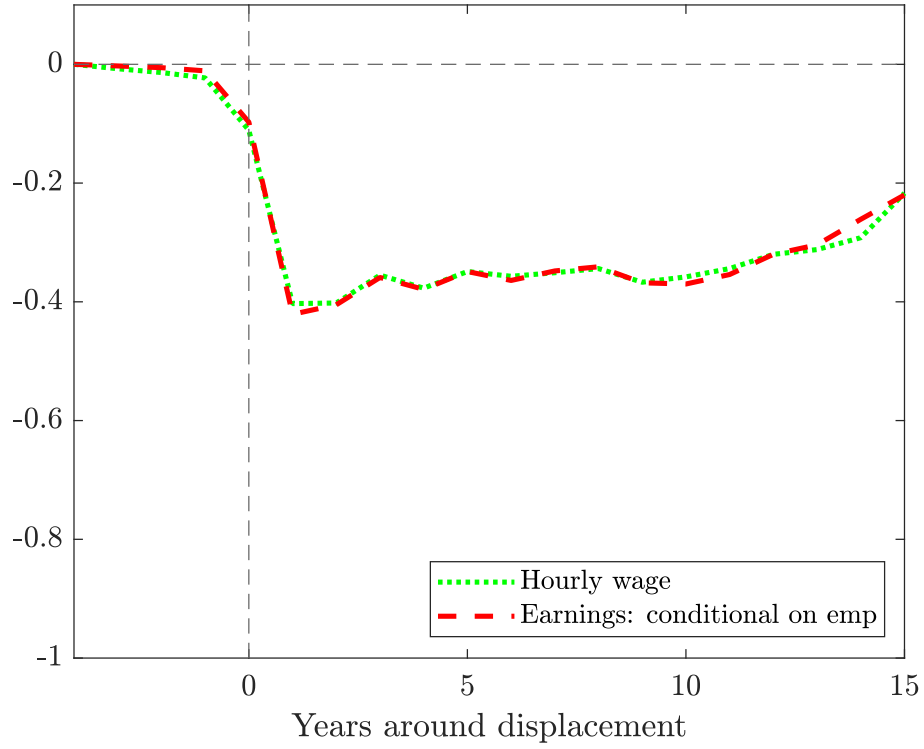
### III RESULTS

Figure 2 shows our main results. Using the baseline control group we include regression results where the dependent variable in (1) takes on hourly wages; weekly earnings conditional on employment; weekly earnings unconditional on employment (including zeros), but where we include only miners who have positive earnings within four years after job loss (similar to [Jacobson et al. \(1993\)](#)); weekly earnings unconditional on employment including all zeros ([Davis and von Wachter, 2012](#); [Schmieder et al., 2022](#); [Bertheau et al., 2022](#)).

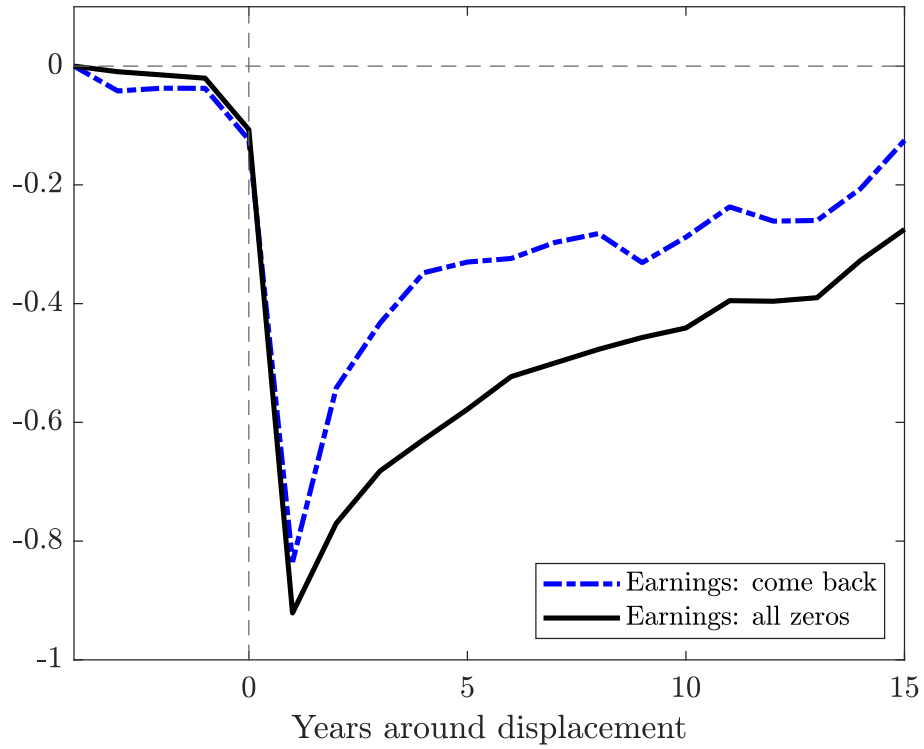
Our estimates show devastating losses for the miners. In the year following job loss, the miners earnings conditional on employment falls by 40% and remains depressed by 20% fifteen years later. These losses are not driven by a reduction in hours worked since the losses in hourly wages (dotted line) and weekly earnings conditional on employment (dashed line) are close to identical.

Unconditional earning losses (solid line) are 90% in the first year, and remain depressed by 30% fifteen years later. Even if we focus on the more conservative earnings losses, where we only include individuals who return to work within four years (dashed-dotted line), the losses are still substantial, at 80% in the first year and 10-20% fifteen years later. Note that we observe these losses despite the existence of regeneration policies, targeting the laid-off miners and the affected communities.

Figure 3 replicates the solid line from Figure 2 with a 95% confidence interval which allows for a statistical comparison of the additional results, determined by varying definitions of treatment and control groups. Neither the change in our treated group, by focusing on the underground miners (dotted line), nor the changes in the definition of the treatment, by focusing on the last separation in locations with coal mine closures (dashed line) lead to a significant difference in the results. On



(a) Wages and earnings conditional on employment



(b) Earnings including zeros

FIGURE 2: The estimated proportional changes in wages and earnings following job loss

Note: “Earnings: come back” refers to the treatment group where we only include those who have positive earnings at some point four years after job loss, while replacing their earnings with a zero if the miner is not observed for any  $k > 0$ . “Earnings: all zeros” refers to the treatment in which we replace the earning of any miners with a zero if the miner is not observed for any  $k > 0$ , without any restrictions.

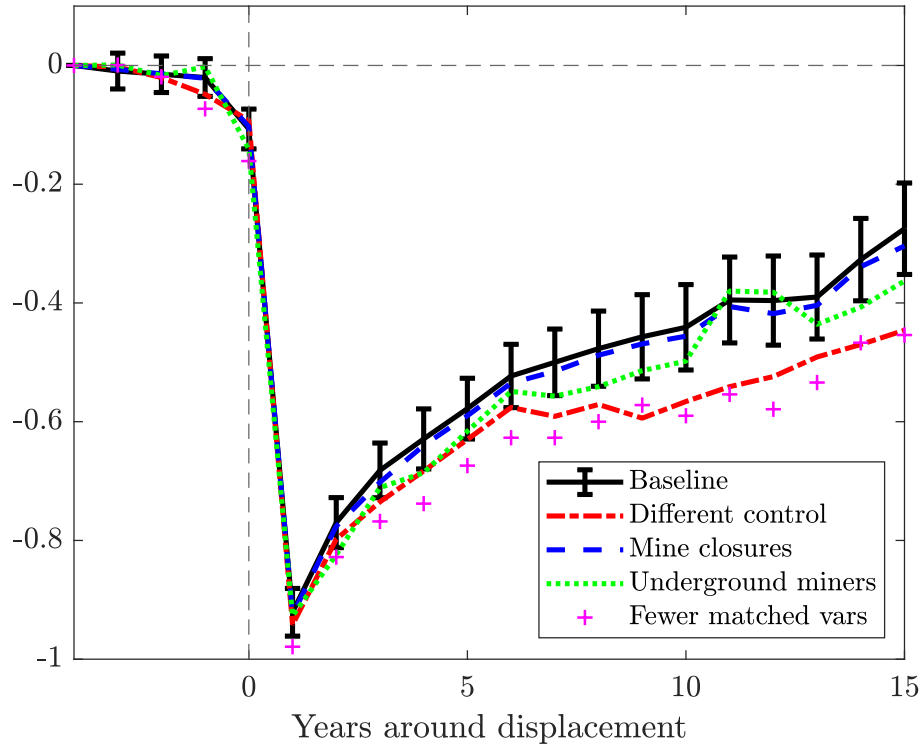


FIGURE 3: The estimated proportional changes in earnings following job loss including all zeros over different treatments and controls

Note: "Baseline" shows the estimated costs as well as the 95% confidence interval of job loss using the baseline control group described in Section II. "Different control" shows the estimated costs of job loss in comparison to a more restricted control group, focusing blue collar manufacturing workers which are involved in the creation of primary metal products consisting of iron, aluminum and copper as well as their alloys. "Mine closure" reports the costs of job loss using the baseline control group where we only include those miners who experienced job loss when a mine also closed in the county. "Underground miners" reports the costs of job loss using the baseline control group, where we only include those miners who are working underground. Finally, "Fewer matched vars" reports the costs of job loss where we only match the miners to a control group with variables age and pre-displacement earnings.

the other hand, our more conservative choice of the control group (dashed-dotted line), in which we focus on blue collar manufacturing workers in primary metal production as well as the matching on age and pre-displacement earnings only (line of crosses), lead to significantly higher estimates of the displacements cost.

In Table 2 we use our baseline specification to estimate the associated losses in present discounted value (PDV) caused by the layoff.<sup>8</sup> We use a 5% discount rate to remain comparable to Davis and von Wachter (2012). We estimate present discounted losses in: earnings conditional on employment, earnings conditional on having positive earnings within four years of displacement, and earnings losses including all zeros. In column (1) our estimates range from 3.8 to 6 years of pre-displacement earnings. 6 years of pre-displacement earnings represent our upper bound estimate and is equivalent to around \$140,000 or £100,000 in 2000 prices. Column (2) shows the present discounted earnings of the miners relative to the control.<sup>9</sup> Including all miners who have been displaced, and assuming that they have zero earnings if they do not reappear in our data set, the miners present discounted earnings were 40% of the counterfactual. This number increases to 60% when we exclude miners who do not reappear in the data after displacement and if we focus on those who remain employed. The final two columns split the losses into those due to losses in earnings conditional on employment and those due to losses in employment. By construction losses in wages were particularly important for the results in the first two rows. However, even if take into account individuals who never return to work, two-thirds of the losses are still explained by the drop in wages while only a third of the losses are explained by a drop in employment.

How do our estimates compare to the previous literature on mass layoffs? Couch and Placzek (2010) reconsider the earnings losses estimated in the seminal work of Jacobson et al. (1993), and also review the literature on mass layoffs. The initial loss tends to be in the range of 25 to 50%, with the largest fall in earnings that they report in the first year after displacement being 66%. In more recent studies, Huckfeldt (2022) finds that workers laid-off during a recession and who switched occupation experienced a first year reduction of 42% in earnings and the relative losses remain around 10-15% a decade later. This is in line with Lachowska et al. (2020) who document first

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<sup>8</sup>The present discounted value of the displacement costs is equal to  $\sum_{k=1}^{15} \frac{\hat{\delta}_k}{(1.05)^{k-1}}$ .

<sup>9</sup>The present discounted earnings for the miners relative to the control is equal to  $\sum_{k=1}^{15} \frac{\hat{y}_k^T}{1.05^{k-1}} / \sum_{k=1}^{15} \frac{\hat{y}_k^C}{1.05^{k-1}}$ , where  $\hat{y}^T$  and  $\hat{y}^C$  indicate the estimated earnings from (1) for the treated and control groups, respectively.



	(1)	(2)	(3)	(4)
	PDV losses as a multiple of predisplacement annual earnings	Miners PDV earnings relative to counterfactual	Due to the losses in wages	Due to the losses in employment
Conditional on employment	3.85	63.9%	100%	0%
Come back	4.02	60.2%	93.8%	6.2%
All zeros	6.01	40.8%	64.0%	36.0%

TABLE 2: The estimated present discounted wage and earnings losses

Note: Column (1) shows the present discounted earnings losses relative to our baseline counterfactual, with the earnings being standardised by the average individual pre-displacement earnings from period  $t - 1$  to  $t - 4$  and displacement taking place between  $t$  and  $t + 1$ :  $\sum_{k=1}^{15} \frac{\hat{\delta}_k}{1.05^{k-1}}$ . Column (2) shows the estimated present discounted earnings of the miners as a proportion of the estimated present discounted earnings of the control group:  $\sum_{k=1}^{15} \frac{\hat{y}_k^T}{1.05^{k-1}} / \sum_{k=1}^{15} \frac{\hat{y}_k^C}{1.05^{k-1}}$ , where  $T$  is the treatment and  $C$  is the control. Columns (3) and (4) split the losses shown in column (1) into those attributable to losses in wages and those due to losses in employment.

year losses of 45-49% that decline to 15-25% after 5 years. [Upward and Wright \(2017\)](#) use data from the British Household Panel Survey and also find the losses to be below 50% in the year after separation. We, on the other hand, find the initial earning losses to be between 80 and 90%, with the initial losses being around 40% only for the sample of those miners who manage to find another job, abstracting from those miners who fail to find alternative employment. [Davis and von Wachter \(2012\)](#) find for the US that the cumulative losses over a period of 20 years are close to 1.7 times the displaced workers pre-displacement earnings, while we find that the miner's losses add up to between 4 and 6 times the pre-displacement earning for a shorter period of 15 years.

## IV FINAL REMARKS

We examine the impact of job displacement on coal miners' earnings. Our analysis exploits individual panel data from the UK and the dramatic collapse of the coal industry that accelerated in mid-1980s. We find evidence of substantial reduction in earnings of displaced miners that persist in the long-term. As far as we know, our estimates are the largest in the literature.

While specific to the UK context, these findings suggest that the phase out of the coal industry, a policy which has been repeatedly proposed as an alternative to reduce carbon emissions, could

impose large costs to coal miners, their families and mining communities that may persist in the long run. The external validity of our results may hinge on location, job and worker characteristics of the existing coal mines around the world. Overall, the phasing out of coal around the world will displace more than 5 million workers, most of them in China (around 3 million). Just as in the case of the UK in the 1980s, coal mining remains an important employer of male workers with low educational attainment in many remote locations of China, United States, Poland, India, Indonesia, Russia or South Africa ([Ruppert Bulmer et al., 2021](#)). In these remote locations, the sector pays relatively higher wages than alternative occupations available, while the capacity of the local labor markets to absorb the displaced miners is limited. All this suggests that the UK experience, given the characteristics of workers and communities in coal mining areas and the speed with which the dissolution of the coal industry took place, makes it similar to the one that coal miners around the world may experience in the upcoming energy transition.

While our analysis can identify the size of the earning losses, we are unable to pin down a possible cause. Previous work suggests that earning losses reflect loss of occupation specific human capital. While this could certainly be the case for coal miners, we cannot rule out other possible factors specific to coal mining in the UK such as compensating differentials (due to the higher risk of mining jobs), union wage premiums, or lower labor mobility. Examining these issues warrant further research.

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# Online appendix for “The job displacement costs of phasing out coal”<sup>\*</sup>

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# 1 Additional figures

We use national statistics on formal employment in the mining industry for the seven biggest exporters and producers to construct the time series in Figure 1. China is by far the largest employer of coal miners in the world, followed by Indonesia, India, Russia, South Africa, United States and Australia. Also, China and India consume most of the extracted coal, such that Russia and South Africa replace these two on the top 5 list of global exporters. In Figure 3, we present the location of industrial mines. As is apparent from the Figure, many of the mines are located in remote parts of the world. Thus, as a result of a coal mine closure miners are displaced in remote locations.

To estimate the global number of active coal miners we proceed as follows. First, we use the last available country level information on active coal miners from Figure 1: 43,250 in Australia (2020), 2,750,460 in China (2021), 274,445 in India (2020), 1,381,180 in Indonesia (2017), 137,819 in Russia (2016), 86,919 in South Africa (2018) as well as 42,583 in the US (2021). Combining this information with [country level statistics on the total number of industrial mines](#) we can calculate the average number of miners per mine for these countries. Applying this estimate to other countries, for which we did not collect national statistics on the number of active coal miners, we get to a total of approximately 5.4 Million active coal miners. Note that this is likely to be lower bound, since we do not account for individuals involved in the informal mining of coal.



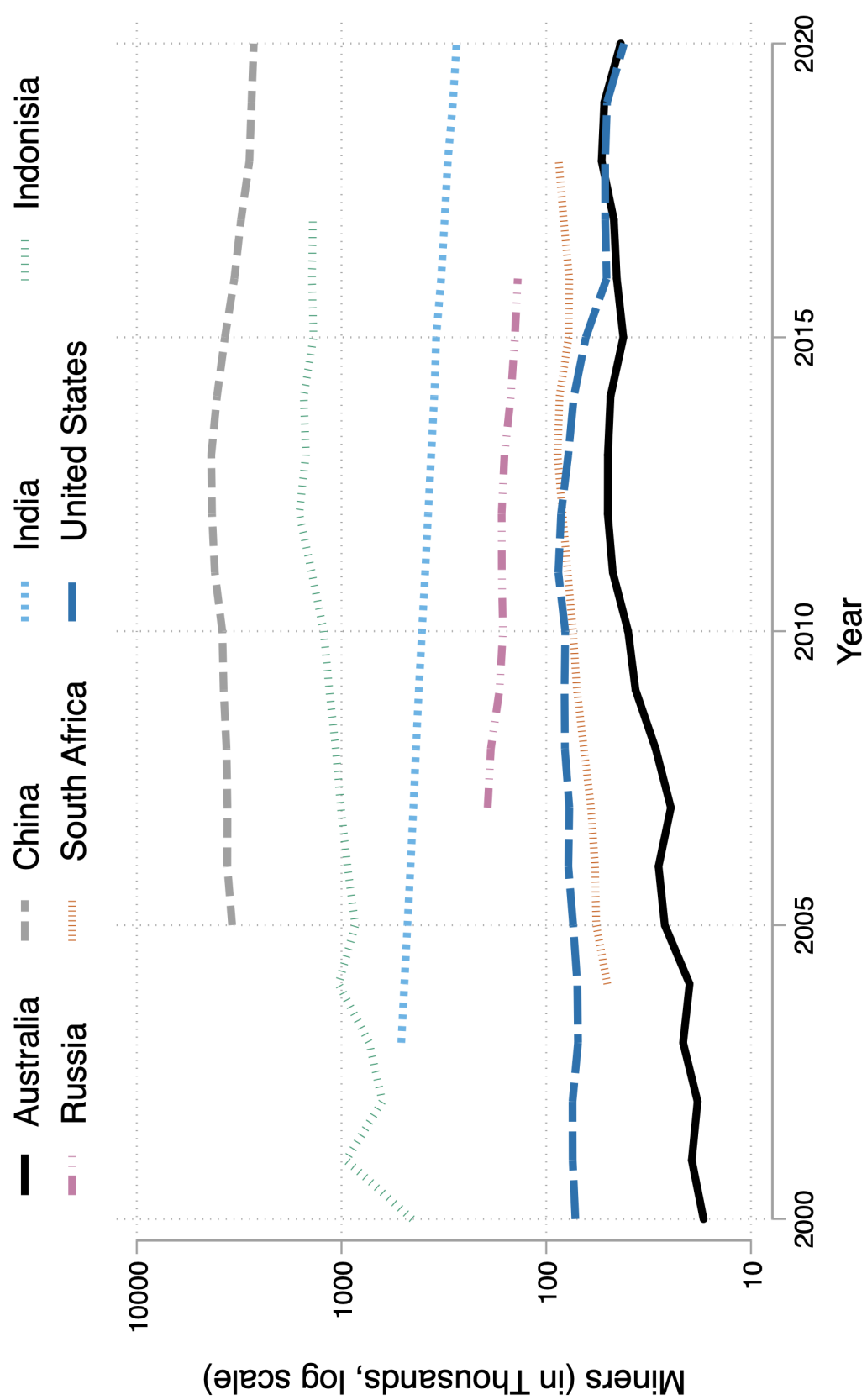


Figure 1: Total number of coal miners by country for the top seven producing and exporting countries

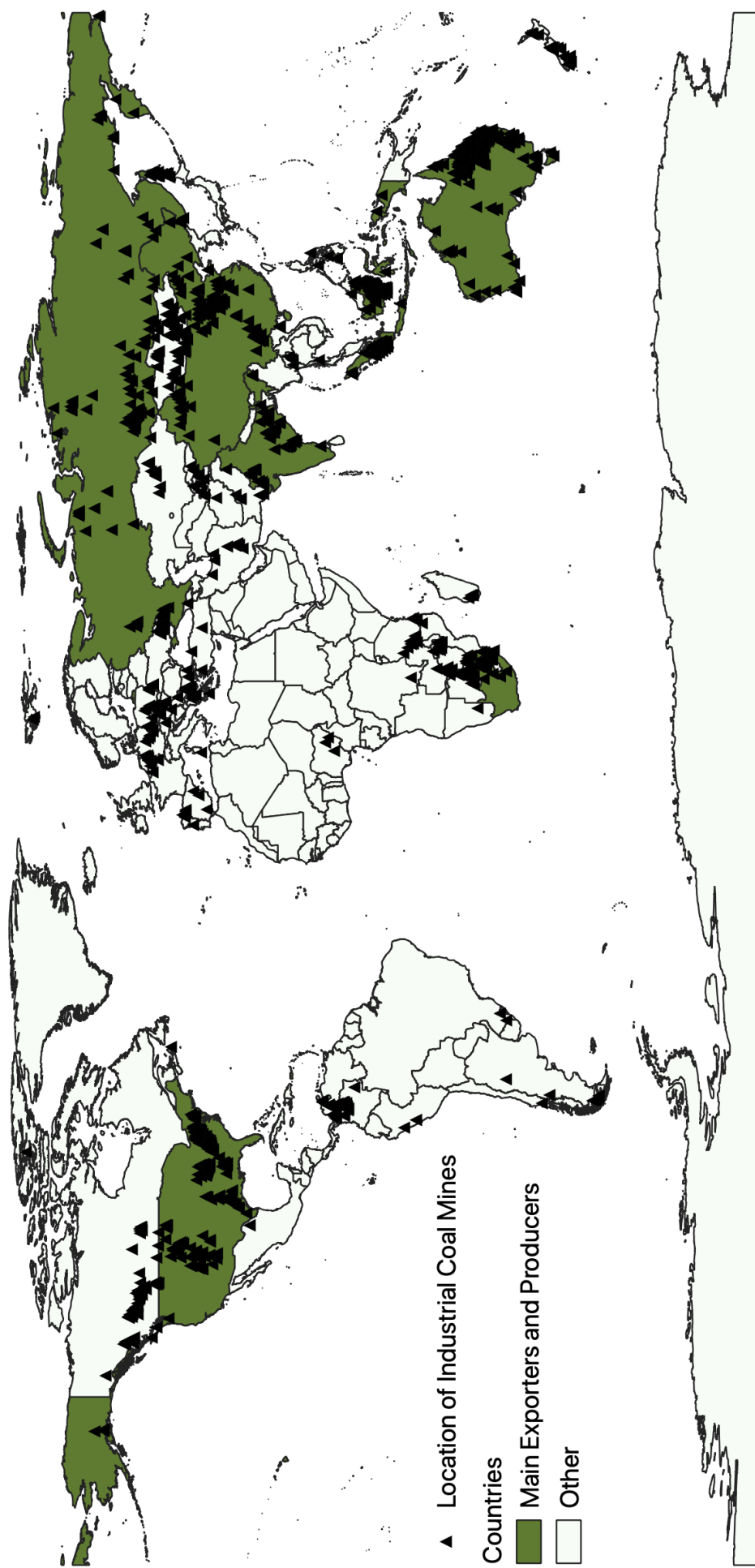


Figure 2: Employment by the top 7 producing and exporting countries

Note: Main exporters and producers are marked in green. The location of coal mines is taken from the SNL Energy Data Set produced by [S&P Global](#) a publicly traded corporation with its primary areas of business are financial information and analytics.

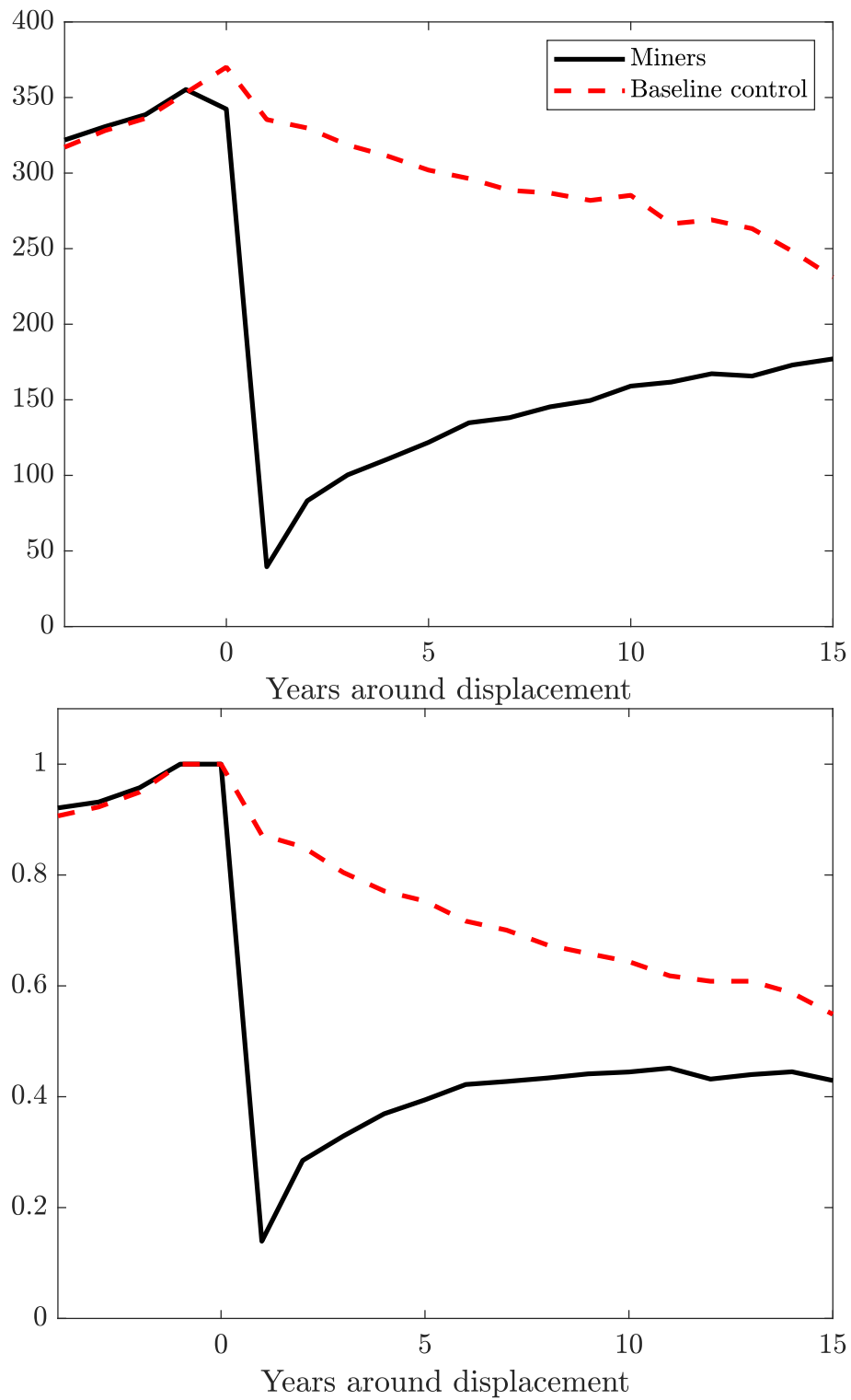


Figure 3: Raw earnings and raw employment of the treated and baseline control group

## 2 Additional tables

The following tables present point estimates of the earnings, wages, employment and hourly wage consequences of displacement. The tables are related to Figure 2 and Figure 3 in the main text. We also include the same consequences where we only look at male workers and where no matching was conducted prior to estimation. This latter exercise includes all manufacturing workers as controls. The results for only males are close to identical to those including females, and the earnings consequences are larger in the long run when not conducting matching prior to estimation.

VARIABLES	(1) Earnings	(2) Wages	(3) Employment	(4) Hourly wage
$\delta_{-3}$	-0.00941 (0.0154)	-0.00273 (0.0127)	-0.00691 (0.0106)	-0.00745 (0.0121)
$\delta_{-2}$	-0.0148 (0.0157)	-0.00565 (0.0131)	-0.00905 (0.0102)	-0.0138 (0.0125)
$\delta_{-1}$	-0.0203 (0.0162)	-0.0110 (0.0142)	-0.0184* (0.00946)	-0.0229* (0.0135)
$\delta_0$	-0.107*** (0.0171)	-0.0973*** (0.0152)	-0.0182* (0.00950)	-0.111*** (0.0145)
$\delta_1$	-0.921*** (0.0205)	-0.421*** (0.0266)	-0.752*** (0.0142)	-0.403*** (0.0258)
$\delta_2$	-0.770*** (0.0215)	-0.405*** (0.0228)	-0.585*** (0.0159)	-0.402*** (0.0224)
$\delta_3$	-0.682*** (0.0235)	-0.359*** (0.0234)	-0.495*** (0.0168)	-0.355*** (0.0221)
$\delta_4$	-0.629*** (0.0258)	-0.379*** (0.0237)	-0.428*** (0.0175)	-0.377*** (0.0216)
$\delta_5$	-0.578*** (0.0261)	-0.349*** (0.0232)	-0.390*** (0.0180)	-0.349*** (0.0217)
$\delta_6$	-0.523*** (0.0272)	-0.364*** (0.0237)	-0.329*** (0.0188)	-0.357*** (0.0218)
$\delta_7$	-0.500*** (0.0286)	-0.348*** (0.0244)	-0.321*** (0.0195)	-0.351*** (0.0232)
$\delta_8$	-0.477*** (0.0323)	-0.341*** (0.0305)	-0.289*** (0.0199)	-0.344*** (0.0290)
$\delta_9$	-0.457*** (0.0362)	-0.368*** (0.0373)	-0.272*** (0.0206)	-0.367*** (0.0343)
$\delta_{10}$	-0.441*** (0.0367)	-0.370*** (0.0410)	-0.254*** (0.0211)	-0.358*** (0.0364)
$\delta_{11}$	-0.395*** (0.0369)	-0.354*** (0.0427)	-0.227*** (0.0215)	-0.344*** (0.0379)
$\delta_{12}$	-0.396*** (0.0383)	-0.320*** (0.0444)	-0.239*** (0.0221)	-0.320*** (0.0425)
$\delta_{13}$	-0.390*** (0.0361)	-0.304*** (0.0381)	-0.233*** (0.0225)	-0.312*** (0.0412)
$\delta_{14}$	-0.327*** (0.0354)	-0.261*** (0.0346)	-0.207*** (0.0234)	-0.292*** (0.0336)
$\delta_{15}$	-0.275*** (0.0393)	-0.220*** (0.0435)	-0.192*** (0.0238)	-0.217*** (0.0593)
R-squared	0.180	0.054	0.324	0.057

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 1: The costs of job loss including all zeros for earnings

Source: New Earnings Survey

VARIABLES	(1) Earnings	(2) Wages	(3) Employment	(4) Hourly wage
$\delta_{-3}$	-0.0418* (0.0243)	-0.00803 (0.0210)	-0.0256* (0.0152)	-0.00800 (0.0196)
$\delta_{-2}$	-0.0372 (0.0244)	-0.0134 (0.0210)	-0.0192 (0.0147)	-0.0161 (0.0198)
$\delta_{-1}$	-0.0374 (0.0256)	-0.0157 (0.0226)	-0.0260* (0.0143)	-0.0215 (0.0214)
$\delta_0$	-0.124*** (0.0284)	-0.0997*** (0.0254)	-0.0292** (0.0144)	-0.107*** (0.0242)
$\delta_1$	-0.835*** (0.0347)	-0.411*** (0.0319)	-0.602*** (0.0237)	-0.394*** (0.0305)
$\delta_2$	-0.542*** (0.0333)	-0.381*** (0.0300)	-0.282*** (0.0248)	-0.379*** (0.0288)
$\delta_3$	-0.433*** (0.0377)	-0.362*** (0.0305)	-0.162*** (0.0251)	-0.358*** (0.0294)
$\delta_4$	-0.348*** (0.0425)	-0.363*** (0.0321)	-0.0702*** (0.0254)	-0.365*** (0.0299)
$\delta_5$	-0.330*** (0.0422)	-0.348*** (0.0309)	-0.0815*** (0.0263)	-0.349*** (0.0291)
$\delta_6$	-0.324*** (0.0436)	-0.359*** (0.0322)	-0.0727*** (0.0273)	-0.353*** (0.0297)
$\delta_7$	-0.297*** (0.0445)	-0.328*** (0.0329)	-0.0898*** (0.0282)	-0.334*** (0.0325)
$\delta_8$	-0.282*** (0.0541)	-0.308*** (0.0480)	-0.0668** (0.0284)	-0.317*** (0.0460)
$\delta_9$	-0.331*** (0.0622)	-0.384*** (0.0635)	-0.0988*** (0.0293)	-0.378*** (0.0589)
$\delta_{10}$	-0.288*** (0.0475)	-0.335*** (0.0429)	-0.0960*** (0.0298)	-0.333*** (0.0412)
$\delta_{11}$	-0.237*** (0.0479)	-0.306*** (0.0458)	-0.0729** (0.0303)	-0.300*** (0.0443)
$\delta_{12}$	-0.261*** (0.0600)	-0.355*** (0.0710)	-0.0682** (0.0315)	-0.355*** (0.0681)
$\delta_{13}$	-0.260*** (0.0556)	-0.317*** (0.0571)	-0.0758** (0.0322)	-0.315*** (0.0601)
$\delta_{14}$	-0.206*** (0.0533)	-0.282*** (0.0492)	-0.0591* (0.0337)	-0.299*** (0.0478)
$\delta_{15}$	-0.125** (0.0566)	-0.241*** (0.0543)	-0.0326 (0.0342)	-0.252*** (0.0523)
R-squared	0.097	0.068	0.186	0.069

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 2: The costs of job loss including all only those who have one year of positive earnings during the four years after job loss

Source: New Earnings Survey

VARIABLES	(1) Earnings	(2) Wages	(3) Employment	(4) Hourly wage
$\delta_{-3}$	-0.00265 (0.0147)	-0.00343 (0.0115)	-0.00401 (0.0107)	-0.00322 (0.0115)
$\delta_{-2}$	-0.0204 (0.0156)	-0.0235* (0.0125)	-0.00882 (0.0107)	-0.0200 (0.0124)
$\delta_{-1}$	-0.0485*** (0.0156)	-0.0386*** (0.0136)	-0.0255*** (0.00961)	-0.0335** (0.0131)
$\delta_0$	-0.0928*** (0.0161)	-0.0838*** (0.0141)	-0.0246** (0.00967)	-0.0818*** (0.0137)
$\delta_1$	-0.942*** (0.0193)	-0.417*** (0.0263)	-0.762*** (0.0143)	-0.379*** (0.0260)
$\delta_2$	-0.798*** (0.0210)	-0.421*** (0.0219)	-0.581*** (0.0161)	-0.414*** (0.0218)
$\delta_3$	-0.735*** (0.0221)	-0.374*** (0.0227)	-0.511*** (0.0167)	-0.369*** (0.0217)
$\delta_4$	-0.683*** (0.0234)	-0.395*** (0.0223)	-0.440*** (0.0174)	-0.402*** (0.0209)
$\delta_5$	-0.630*** (0.0244)	-0.387*** (0.0225)	-0.389*** (0.0180)	-0.391*** (0.0218)
$\delta_6$	-0.576*** (0.0263)	-0.385*** (0.0239)	-0.343*** (0.0187)	-0.380*** (0.0232)
$\delta_7$	-0.591*** (0.0279)	-0.395*** (0.0255)	-0.338*** (0.0192)	-0.398*** (0.0246)
$\delta_8$	-0.571*** (0.0292)	-0.371*** (0.0279)	-0.327*** (0.0196)	-0.377*** (0.0273)
$\delta_9$	-0.594*** (0.0329)	-0.414*** (0.0329)	-0.327*** (0.0202)	-0.399*** (0.0312)
$\delta_{10}$	-0.566*** (0.0344)	-0.382*** (0.0358)	-0.320*** (0.0204)	-0.371*** (0.0336)
$\delta_{11}$	-0.541*** (0.0320)	-0.371*** (0.0297)	-0.304*** (0.0211)	-0.362*** (0.0295)
$\delta_{12}$	-0.524*** (0.0351)	-0.327*** (0.0356)	-0.302*** (0.0218)	-0.308*** (0.0360)
$\delta_{13}$	-0.491*** (0.0364)	-0.344*** (0.0356)	-0.272*** (0.0225)	-0.330*** (0.0399)
$\delta_{14}$	-0.470*** (0.0406)	-0.347*** (0.0431)	-0.248*** (0.0233)	-0.342*** (0.0418)
$\delta_{15}$	-0.446*** (0.0392)	-0.277*** (0.0412)	-0.258*** (0.0238)	-0.240*** (0.0577)
R-squared	0.205	0.072	0.322	0.069

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 3: The costs of job loss including all zeros for earnings for a different control group

Note: We classify control workers based on whether they belong to the following standard industrial classification groups - 311, 312, 313, 321, 322, 333 (before 1984), 2210, 2220, 2234, 2235, 2245, 2246, 2247 (after 1984). These classifications include “forging, pressing and stamping” and “foundering”. Source: New Earnings Survey

VARIABLES	(1) Earnings	(2) Wages	(3) Employment	(4) Hourly wage
$\delta_{-3}$	-0.00656 (0.0160)	0.000488 (0.0132)	-0.00489 (0.0108)	-0.00847 (0.0129)
$\delta_{-2}$	-0.0141 (0.0164)	-0.00558 (0.0136)	-0.00591 (0.0105)	-0.0138 (0.0128)
$\delta_{-1}$	-0.0216 (0.0170)	-0.00918 (0.0149)	-0.0186* (0.00982)	-0.0258* (0.0149)
$\delta_0$	-0.103*** (0.0180)	-0.0912*** (0.0160)	-0.0182* (0.00987)	-0.138*** (0.0316)
$\delta_1$	-0.925*** (0.0212)	-0.433*** (0.0283)	-0.758*** (0.0147)	-0.435*** (0.0290)
$\delta_2$	-0.776*** (0.0223)	-0.414*** (0.0239)	-0.588*** (0.0166)	-0.359*** (0.0557)
$\delta_3$	-0.702*** (0.0244)	-0.378*** (0.0243)	-0.507*** (0.0175)	-0.367*** (0.0238)
$\delta_4$	-0.640*** (0.0270)	-0.390*** (0.0249)	-0.429*** (0.0183)	-0.382*** (0.0248)
$\delta_5$	-0.590*** (0.0273)	-0.363*** (0.0242)	-0.396*** (0.0187)	-0.358*** (0.0232)
$\delta_6$	-0.535*** (0.0283)	-0.374*** (0.0247)	-0.333*** (0.0197)	-0.369*** (0.0238)
$\delta_7$	-0.515*** (0.0297)	-0.365*** (0.0257)	-0.326*** (0.0203)	-0.374*** (0.0269)
$\delta_8$	-0.488*** (0.0339)	-0.368*** (0.0317)	-0.287*** (0.0208)	-0.370*** (0.0308)
$\delta_9$	-0.469*** (0.0382)	-0.386*** (0.0394)	-0.275*** (0.0215)	-0.384*** (0.0369)
$\delta_{10}$	-0.456*** (0.0377)	-0.401*** (0.0416)	-0.249*** (0.0220)	-0.386*** (0.0374)
$\delta_{11}$	-0.406*** (0.0388)	-0.375*** (0.0455)	-0.228*** (0.0225)	-0.369*** (0.0410)
$\delta_{12}$	-0.418*** (0.0396)	-0.347*** (0.0462)	-0.243*** (0.0231)	-0.350*** (0.0452)
$\delta_{13}$	-0.404*** (0.0378)	-0.315*** (0.0403)	-0.240*** (0.0236)	-0.330*** (0.0447)
$\delta_{14}$	-0.339*** (0.0368)	-0.280*** (0.0364)	-0.208*** (0.0245)	-0.310*** (0.0363)
$\delta_{15}$	-0.304*** (0.0391)	-0.259*** (0.0410)	-0.198*** (0.0250)	-0.226*** (0.0562)
R-squared	0.183	0.056	0.326	0.038

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 4: The costs of job loss including all zero earnings and where job loss coincides with the closure of a mine at the county level

Source: New Earnings Survey



VARIABLES	(1) Earnings	(2) Wages	(3) Employment	(4) Hourly wage
$\delta_{-3}$	-0.00813 (0.0158)	-0.00154 (0.0130)	-0.00443 (0.0108)	-0.00662 (0.0125)
$\delta_{-2}$	-0.0135 (0.0161)	-0.00441 (0.0134)	-0.00601 (0.0103)	-0.0124 (0.0128)
$\delta_{-1}$	-0.0238 (0.0166)	-0.0118 (0.0145)	-0.0163* (0.00933)	-0.0235* (0.0139)
$\delta_0$	-0.111*** (0.0175)	-0.0996*** (0.0155)	-0.0159* (0.00938)	-0.112*** (0.0150)
$\delta_1$	-0.910*** (0.0208)	-0.421*** (0.0274)	-0.758*** (0.0143)	-0.410*** (0.0269)
$\delta_2$	-0.764*** (0.0219)	-0.399*** (0.0232)	-0.591*** (0.0161)	-0.404*** (0.0229)
$\delta_3$	-0.676*** (0.0240)	-0.347*** (0.0238)	-0.503*** (0.0171)	-0.354*** (0.0227)
$\delta_4$	-0.628*** (0.0265)	-0.371*** (0.0242)	-0.442*** (0.0178)	-0.380*** (0.0222)
$\delta_5$	-0.575*** (0.0266)	-0.344*** (0.0235)	-0.399*** (0.0183)	-0.353*** (0.0222)
$\delta_6$	-0.523*** (0.0278)	-0.366*** (0.0240)	-0.335*** (0.0192)	-0.367*** (0.0224)
$\delta_7$	-0.500*** (0.0293)	-0.345*** (0.0249)	-0.333*** (0.0200)	-0.355*** (0.0239)
$\delta_8$	-0.483*** (0.0333)	-0.342*** (0.0311)	-0.303*** (0.0204)	-0.348*** (0.0300)
$\delta_9$	-0.456*** (0.0374)	-0.374*** (0.0383)	-0.276*** (0.0212)	-0.378*** (0.0358)
$\delta_{10}$	-0.441*** (0.0379)	-0.369*** (0.0421)	-0.262*** (0.0217)	-0.364*** (0.0379)
$\delta_{11}$	-0.397*** (0.0381)	-0.358*** (0.0440)	-0.235*** (0.0222)	-0.358*** (0.0394)
$\delta_{12}$	-0.394*** (0.0395)	-0.326*** (0.0459)	-0.242*** (0.0227)	-0.337*** (0.0442)
$\delta_{13}$	-0.393*** (0.0370)	-0.306*** (0.0390)	-0.245*** (0.0231)	-0.320*** (0.0427)
$\delta_{14}$	-0.323*** (0.0363)	-0.258*** (0.0352)	-0.213*** (0.0240)	-0.295*** (0.0346)
$\delta_{15}$	-0.263*** (0.0404)	-0.219*** (0.0446)	-0.187*** (0.0246)	-0.230*** (0.0622)
R-squared	0.184	0.055	0.335	0.058

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 5: The costs of job loss for men only including all zeros for earnings

Source: New Earnings Survey

VARIABLES	(1) Earnings	(2) Wages	(3) Employment	(4) Hours
$\delta_{-3}$	-0.0150 (0.0102)	-0.00588 (0.00856)	-0.0185*** (0.00690)	-0.00647 (0.00835)
$\delta_{-2}$	-0.0430*** (0.0109)	-0.0302*** (0.00937)	-0.0306*** (0.00686)	-0.0295*** (0.00907)
$\delta_{-1}$	-0.136*** (0.0111)	-0.0468*** (0.00989)	-0.121*** (0.00651)	-0.0455*** (0.00949)
$\delta_0$	-0.190*** (0.0119)	-0.102*** (0.0107)	-0.120*** (0.00653)	-0.0996*** (0.0102)
$\delta_1$	-0.995*** (0.0135)	-0.425*** (0.0238)	-0.840*** (0.0102)	-0.400*** (0.0233)
$\delta_2$	-0.842*** (0.0144)	-0.419*** (0.0188)	-0.650*** (0.0121)	-0.409*** (0.0188)
$\delta_3$	-0.780*** (0.0152)	-0.383*** (0.0190)	-0.574*** (0.0126)	-0.371*** (0.0180)
$\delta_4$	-0.745*** (0.0158)	-0.408*** (0.0182)	-0.512*** (0.0130)	-0.403*** (0.0164)
$\delta_5$	-0.710*** (0.0161)	-0.409*** (0.0177)	-0.470*** (0.0133)	-0.403*** (0.0167)
$\delta_6$	-0.677*** (0.0168)	-0.420*** (0.0177)	-0.429*** (0.0137)	-0.413*** (0.0164)
$\delta_7$	-0.680*** (0.0175)	-0.426*** (0.0182)	-0.421*** (0.0141)	-0.424*** (0.0170)
$\delta_8$	-0.658*** (0.0178)	-0.413*** (0.0196)	-0.401*** (0.0143)	-0.414*** (0.0189)
$\delta_9$	-0.650*** (0.0184)	-0.435*** (0.0199)	-0.385*** (0.0146)	-0.433*** (0.0187)
$\delta_{10}$	-0.616*** (0.0205)	-0.421*** (0.0241)	-0.368*** (0.0149)	-0.418*** (0.0227)
$\delta_{11}$	-0.611*** (0.0197)	-0.425*** (0.0218)	-0.354*** (0.0151)	-0.420*** (0.0222)
$\delta_{12}$	-0.586*** (0.0227)	-0.371*** (0.0279)	-0.357*** (0.0155)	-0.367*** (0.0292)
$\delta_{13}$	-0.580*** (0.0220)	-0.404*** (0.0247)	-0.335*** (0.0159)	-0.407*** (0.0311)
$\delta_{14}$	-0.551*** (0.0222)	-0.390*** (0.0234)	-0.317*** (0.0163)	-0.407*** (0.0240)
$\delta_{15}$	-0.541*** (0.0266)	-0.347*** (0.0339)	-0.328*** (0.0167)	-0.328*** (0.0535)
R-squared	0.490	0.703	0.345	0.702

Robust standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 6: The costs of job loss including all zeros for earnings where we do not perform a matching exercise prior to estimation

Source: New Earnings Survey