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DISCUSSION PAPER SERIES

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Uwe Blien
IAB, University of Bamberg and IZA

Wolfgang Dauth
University of Würzburg, IAB and IZA

Duncan Roth
IAB

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Occupational Routine-Intensity and the Costs of Job Loss: Evidence from Mass Layoffs

This paper analyses how differences in the degree of occupational routine-intensity affect the costs of job loss. We use worker-level data on mass layoffs in Germany between 1980 and 2010 and provide causal evidence that workers who used to be employed in more routine-intensive occupations suffer larger and more persistent earnings losses after the mass layoff. Furthermore, we are able to show that, at least initially, earnings losses are primarily due to a reduction in the number of days in employment, suggesting that routine-intensive workers face considerable frictions in the adjustment to job loss. Conditional on finding a new job, routine-intensive workers are more likely to change their occupations but end up systematically in the lower end of their new occupation's wage distribution.

JEL Classification: J24, J63 O33

Keywords: routine-replacing technological change, routine-intensity, labour market biographies, mass layoffs, Germany, difference-in-differences

Corresponding author:
Uwe Blien
Institute for Employment Research (IAB)
Regensburger Straße 104
90478 Nürnberg
Germany
Email: uwe.blien@iab.de

1 Introduction and background

Technological progress has often been the source of concerns about potentially negative effects on employment. On the one hand, these concerns refer to the general level of employment which are commonly discussed under the label of 'technological unemployment' (the term is often attributed to Keynes, 2010, though it is much older). On the other hand, certain groups of workers appear to be at a larger risk of job loss than others. As modern computer controlled technology is particularly suited to executing algorithms, i.e. repeatedly following a fixed set of rules, it is potentially able to substitute workers whose jobs primarily consist of performing routine tasks (Autor et al., 2003; Spitz-Oener, 2006). 'Routine-replacing technological change' has since been established as a well-documented stylized fact (Autor and Salomons, 2017; Biagi et al., 2018). From an aggregate perspective, this form of technical progress is often associated with a polarisation of the labour market since routine-intensive occupations are mostly located in the middle of the wage distribution in many countries (e.g. Autor and Dorn, 2013; Goos et al., 2014; Fonseca et al., 2018).

Recent papers have focused on outcomes at the individual level, thereby addressing the question how technological progress has affected the careers of routine workers. In our paper, we extend this research agenda by addressing the frictions that these workers meet, especially in the form of involuntary unemployment. We compare the fates of workers in jobs with different degrees of routine-intensity. We focus on the population of workers displaced during mass layoffs in their respective firms. All those workers experience the same exogenous shock to their employment biography and are forced to adjust to this shock by searching for a new job. However, the resulting decline in employment and wages is worse for workers in more routine-intensive occupations. This mirrors the fact that demand for routine labour is shrinking, while occupations that involve human interaction and complex, time varying, and creative tasks are complements to new technologies. With this paper, we intend to provide new insights on the impact of modern technologies on individual labour market outcomes such as employment and earnings perspectives.

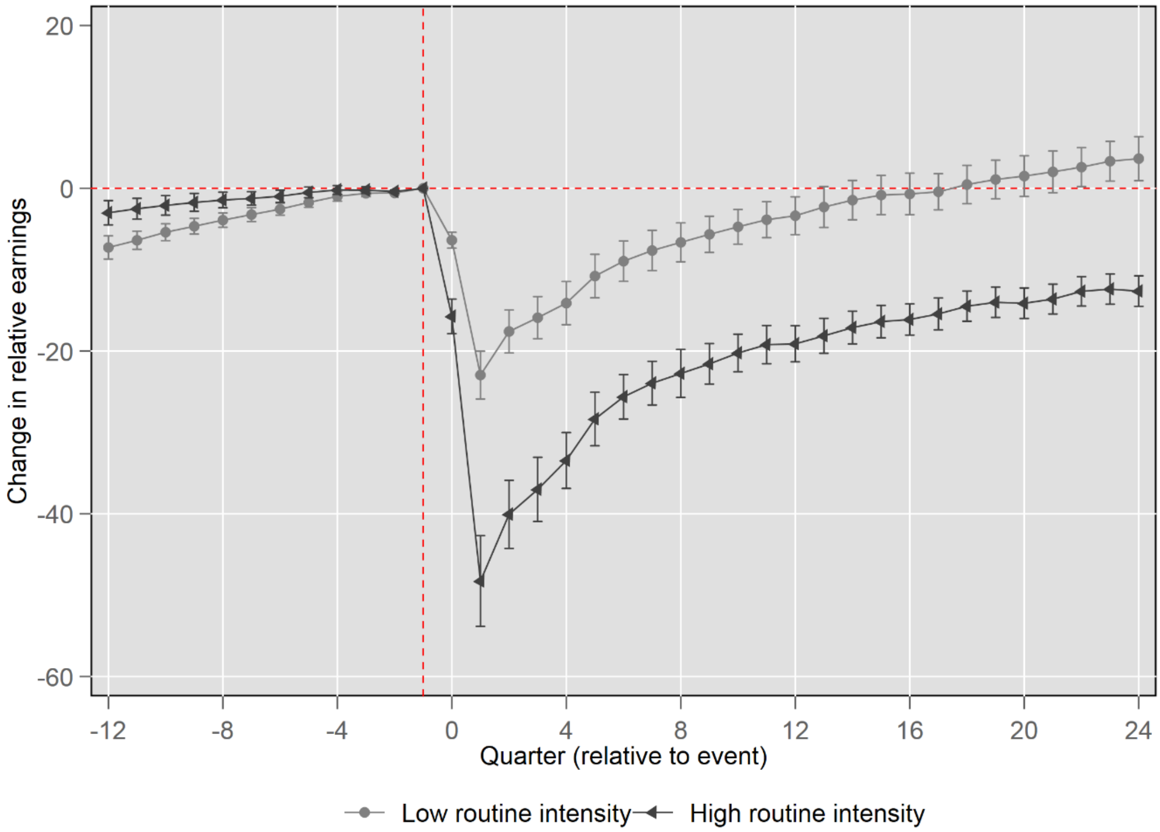
The individual perspective entails several crucial selection issues. First, it is ex ante unclear if and how technological change causes job mobility because incumbent workers may be shielded from the effects of technological change. Even if new technologies could potentially replace human labour, institutions might prevent employers from actually using this technology at will. Job protection laws make it costly for employers to replace workers with machines. Depending on how easily they can be re-trained, incumbent workers are either assigned to a different function or kept at their original job. Especially in European countries, this is amplified by the tendency of labour unions and work councils to protect insiders from labour-saving technological change (Lommerud and Straume, 2011). This creates an insider/outsider distinction on how technological change will affect workers. We therefore focus on a group of workers that is particularly vulnerable: Workers who lost their job during a mass layoff. Those workers face an exogenous shock to their employment biography and previous research has shown that this causes a large and persistent earnings loss (Jacobson et al., 1993; Davis and von Wachter, 2011). We analyse if the magnitude of this loss is systematically related to the routine-intensity of the occupation performed before the layoff.[1]

The second major concern is that workers select into occupations for reasons that are potentially correlated with subsequent labour market outcomes. If routine-intensive jobs require fewer formal skills and offer smaller wages than non-routine jobs, workers with lower (observed and unobserved) skills select into those jobs. It is therefore not clear how much of the difference in labour market

[1] In Germany, larger firms that do not lay off their entire workforce must develop a 'social plan' for a mass layoff, which essentially sorts workers according to their tenure and not according to their skills. The probability of job loss during a mass layoff is therefore unlikely to be correlated with the routine-intensity of the previous job.

outcomes between routine and non-routine workers can actually be attributed to routine-replacing technological change and how much to selection on observable or unobservable skills.

Figure 1: The impact of mass layoffs on earnings by routine-intensity



<u>Notes:</u> Estimates of time-to-event dummies from regressions of relative earnings that also controls for individual fixed effects and quarter dummies. Coefficient estimates of the time-to-event dummies are relative to quarter directly preceding the mass layoff. Vertical bars indicate the estimated 95% confidence interval based on standard errors that are clustered at the level of 83 occupations. 'Low routine-intensity' uses observations of individuals who during the first quarter before the mass layoff are employed in occupations that fall into the bottom quartile of the distribution of routine-intensity. 'High routine-intensity' refers to the top quartile of the distribution of routine-intensity. Sources: IEB, BIBB-IAB employee survey.

To address those concerns, we modify an event study design in the spirit of Jacobson et al. (1993) and Davis et al. (2011) to analyse if the routine-intensity of a worker's previous job affects the chances to subsequently return to the previous earnings level. Figure 1 provides an outlook on the idea underlying our empirical approach. It shows the coefficient estimates of dummy variables indicating the number of quarters before/after displacement from a panel-data regression of earnings (normalized by pre-layoff earnings) on worker-fixed effects and time fixed effects, which is the standard procedure in the literature on mass layoffs. We estimate this model separately for individuals who used to be employed in the top and the bottom quartile of the routine-intensity distribution before the mass layoff. The earnings profiles show that the relative earnings drop is considerably larger for workers from routine-intensive occupations both, immediately after the displacement and persistently over the next six years. However, one might object that workers in occupations at the extremes of the distribution of routine-intensity are not comparable in many ways. In our main specification, we therefore interact the time-to-event indicators with a continuous measure of routine-intensity. This means that our estimates for the impact of routine-intensity on the costs of displacement are tightly identified by small differences in routine-intensity of otherwise similar workers. However, one remarkable finding of Figure 1 is that the earnings profiles prior to displacement are extremely similar for workers in both groups, despite the arguably different nature of those occupations. Our results indicate that on average mass layoffs severely and persistently reduce earnings, but that this effect becomes more pronounced as the degree of routine-intensity increases. This stems mostly from an additional negative effect of routine-intensity on the number of days in employment after the layoff, while the additional negative effect on wages is significant but more modest. Moreover, we find that the initial degree of routine-intensity increases the probability of switching to a different occupation and that such workers earn below-average wages in their new occupations. A plausible explanation of these findings is that technological progress has reduced the demand for routine-intensive labour, which increases the costs of adjusting to job loss for workers initially employed in such occupations.

Our paper is most closely related to other studies that assess the consequences of technical progress for individual workers. Cortes (2016) develops a general equilibrium model that predicts a distinct pattern of selective mobility out of declining routine occupations. This is in line with individual data from the US, where higher skilled routine workers move to non-routine cognitive jobs and low skilled routine workers move to non-routine manual jobs. In a paper by Cortes et al. (2017) the authors develop a model similar to the one by Autor and Dorn (2013). In this model workers decide between employment and non-employment and between routine and manual work. With higher levels of automation, the demand for routine workers decreases and so does their wage. In the end, workers switch to manual jobs or drop out of employment. The authors conclude that this corresponds to their empirical findings. One difference to our paper is that in their framework unemployment can only be voluntarily, whereas we include involuntary unemployment too. This is similar to the empirical analysis by Bachmann et al. (2019), who study the adjustment of German workers to routine-biased technological change and find that more routine-intensive workers are more likely to lose their jobs.

A related literature studies the cost of occupational mobility. While changing jobs is generally assumed to entail the loss of specific human capital, Gathmann and Schönberg (2010) argue that human capital is in fact task-specific. This implies that job mobility to an occupation that requires a similar set of tasks does not necessarily lead to wage losses. This is corroborated by recent findings of Robinson (2018), who shows that displaced workers are particularly at risk of losing this specific human capital because they are often forced to switch to different occupations that either use different skills compared to the previous occupation or the same skills but at a lower intensity. In the context of our paper, this means that workers in routine-intensive occupations have a twofold problem: They are exogenously forced to find a new job while their old occupation is eroding due to routine-replacing technological change. We therefore expect the costs of displacement increase with an occupation's routine-intensity. Cortes and Gallipoli (2018) show that task-specific costs that arise, for example, when switching out of routine-intensive jobs, account for around 15 percent of the total switching costs. This is also in line with the recent work by Edin et al. (2019), who find that workers in declining occupations face severe income and employment losses, which they explain by an increased need for retraining as well as increased probability of unemployment. The magnitude of these effects does not appear to depend on the specific cause of the occupational decline. We, by contrast, focus on technological change as, arguably, the most important systematic driver of occupational decline.

While we emphasise the role of technological progress as the driving force behind the developments described in this paper, we acknowledge that other factors may also be relevant in explaining the fact that the costs of job loss are larger among routine-intensive workers. Autor et al. (2015) assess the relative importance of technological progress and international trade and find that those sectors that are most affected by imports also employ a relatively high share of routine labour. Moreover, if routine tasks can also be performed abroad, firms may have an incentive to off-shore parts of their employment (Hummels et al., 2018; Oldenski, 2014).

Our paper differs from others by explicitly including unemployment in the research design. Unemployment can be involuntary in the sense that unemployed workers would be ready to accept new jobs at the current wage on the market. However, due to the shrinking demand (for routine work) they are not able to find one. Often they have to switch to other occupations. However, there are barriers according to the qualifications needed to perform the new occupation. For routine workers many frictions are important. For them, it is not easy to take find employment in occupations with a lower degree of routinisation. The qualifications they acquired are often obsolete due to technological progress. In our paper, we allow for the effects of search frictions. We therefore complement other papers, which assume that workers can move easily into non-routine occupations. Like those papers, we also look at the wage reaction, which is associated with the external shock.

The structure of the remainder of the paper is as follows. Besides introducing the dataset, Section 2 explains how we identify workers who experienced mass layoff and compares the characteristics of these workers with workers not involved in a mass layoff. Moreover, we discuss our measure of occupational routine-intensity. The empirical model and the identification of the additional costs due to differences in routine-intensity are the topics of Section 3. The results of our analysis are presented in Section 4. After showing the estimated average impact of mass layoffs on earnings, we discuss how these effects differ depending on the initial degree of routine-intensity and decompose these effects to identify the underlying mechanisms. In addition, we analyse the transitions into different forms of employment after the mass layoff as well as effect heterogeneity across different groups of workers. Section 5 concludes.

2 Data and variables

The purpose of this section is to describe the dataset and the main variables of the empirical analysis. The first subsection documents how we identify the establishments that experienced mass layoff and how we match information on the workers that were employed at those establishments before the mass layoff. We then provide information about establishment and worker characteristics and compare them with a random sample of workers who were not involved in a mass layoff. The second subsection introduces our measure of occupational routine-intensity.

2.1 Identification of mass layoffs

Constructing a dataset of workers who experienced mass layoff first requires identifying those establishments in which such an event occurred. To this end, we follow established contributions to the mass layoff literature (in particular, Davis and von Wachter, 2011). We use the full sample of all plants in Germany observed on June 30 of each year between 1978 and 2014 provided by the IAB Establishment History Panel (BHP). We identify all plants with at least 50 employees on June 30 of one year that contracted by between 30 and 100 percent by June 30 in the next year but had a stable workforce before this incident and did not recover in the years after. We furthermore employ the heuristic of Hethey-Maier and Schmieder (2010) and drop all cases where a significant share of former employees switch to the same new establishment, raising the suspicion of being actually due to the restructuring of plants within the same firm rather than an actual mass layoff.[2]

In the next step, we draw the full labour market biographies of all workers that were employed in one of the previously identified plants at the onset of a mass layoff but lost their job during the following year. This information comes from the Integrated Employment Biographies (IEB, version 13.00.01), which contain information on all labour market participants in Germany (except for civil servants and the self-employed). Based on this data we construct an individual-level panel data set at quarterly

[2] See section A1 in the supplementary Online Appendix for a detailed description on how we identify mass layoffs.

frequency, containing the number of days in employment as well as total earnings per quarter. Each worker in the dataset is observed for 12 quarters before and for up to 24 quarters after the mass layoff.

Table 1: Worker characteristics

		1980-1989		1990-1999		2000-2010		1980-2010
	ML	Comparison	ML	Comparison	ML	Comparison	ML	Comparison
Earnings (quarterly)	8,692.86	8,772.27	10,099.25	9,696.48	11,371.90	10,675.15	10,119.61	9,755.57
	(4,011.29)	(4,349.58)	(6,422.76)	(5,991.01)	(9,589.24)	(8,182.60)	(7,186.82)	(6,459.08)
Days in employment (quarterly)	91.49	90.61	91.52	90.65	91.50	90.67	91.51	90.65
	(0.70)	(4.61)	(0.67)	(4.34)	(0.68)	(4.09)	(0.68)	(4.34)
Average daily wage	95.01	96.74	110.36	106.86	124.28	117.58	110.59	107.51
	(43.83)	(47.59)	(70.15)	(65.68)	(104.74)	(89.80)	(78.50)	(70.83)
Female	26.83	30.97	29.32	33.48	26.25	29.17	27.65	31.40
	(44.31)	(46.24)	(45.53)	(47.19)	(44.00)	(45.45)	(44.73)	(46.41)
Foreign	15.45	12.45	11.18	8.94	8.13	7.97	11.38	9.60
	(36.14)	(33.01)	(31.51)	(28.54)	(27.32)	(27.09)	(31.75)	(29.46)
Age	38.23	39.71	37.65	37.15	39.13	37.10	38.29	37.84
	(7.38)	(8.09)	(7.05)	(7.90)	(6.48)	(7.37)	(7.00)	(7.87)
Tenure	7.93	6.86	9.50	7.45	10.17	7.38	9.28	7.26
	(2.80)	(2.72)	(5.40)	(4.70)	(5.99)	(4.80)	(5.12)	(4.29)
Skill: low	27.77	26.34	15.48	13.73	12.87	9.39	18.04	15.82
	(44.78)	(44.05)	(36.18)	(34.42)	(33.49)	(29.18)	(38.45)	(36.49)
Skill: medium	68.61	68.49	75.99	76.97	75.07	75.60	73.66	74.19
	(46.41)	(46.45)	(42.72)	(42.10)	(43.26)	(42.95)	(44.05)	(43.76)
Skill: high	3.62	5.17	8.53	9.30	12.06	15.01	8.31	9.99
	(18.69)	(22.14)	(27.93)	(29.04)	(32.56)	(35.72)	(27.60)	(29.99)
Agriculture/Fishing	0.11	0.14	0.07	0.16	0.11	0.20	0.09	0.17
	(3.30)	(3.70)	(2.70)	(4.02)	(3.31)	(4.42)	(3.08)	(4.07)
Mining/Quarrying	0.14	0.14	0.08	0.07	0.01	0.01	0.08	0.07
	(3.74)	(3.73)	(2.84)	(2.59)	(1.22)	(1.20)	(2.76)	(2.65)
Manufacturing	56.08	51.82	48.71	46.30	41.42	40.07	48.40	45.82
	(49.63)	(49.97)	(49.98)	(49.86)	(49.26)	(49.00)	(49.97)	(49.83)
Technical occupations	10.24	10.21	12.14	10.54	12.56	10.93	11.26	10.57
	(30.32)	(30.28)	(32.66)	(30.70)	(33.14)	(31.21)	(31.61)	(30.75)
Services	33.43	37.69	39.00	42.93	45.90	48.79	39.41	43.37
	(47.18)	(48.46)	(48.78)	(49.50)	(49.83)	(49.99)	(48.87)	(49.56)
Observations	86,310	172,620	125,942	251,884	100,382	200,764	312,634	625,268

Notes: The table shows the share of workers in percentage points as well as the corresponding standard deviations for various individual-level characteristics. The columns 'ML' show the values for those workers who experienced a mass layoff (measured at the quarter directly preceding the mass layoff). The columns 'Comparison' show the values for a randomly chosen group of workers who did not experience mass layoff, but who satisfy the same conditions as the workers in the mass layoff sample (e.g. age and minimum level of tenure). Source: IEB.

We restrict the sample to those individuals who were aged between 25 and 50 at the time of the mass layoff and who had been in regular full-time employment for the three years before the event. These restrictions are imposed because it is unclear how workers are affected by a mass layoff if they are only loosely attached to a plant in the first place or if they are close to retirement age. We therefore focus on individuals who, in the absence of such an event, would be expected to continue working at the establishment. As mass layoff establishments are identified by comparing the development of employment levels over a one-year period, all workers are included in the sample who were employed at such an establishment during that period. This implies that even if some workers left in anticipation of the mass layoff, they would still be included in the sample as long as their departure fell into this one-year window.

The focus on individuals who were displaced during a mass layoff might raise the objection that they are not representative of the full population of employees in Germany. We therefore compare the workers in our mass layoff sample to a sample of randomly drawn workers who satisfy the same conditions with respect to age and tenure as the mass layoff sample.[3] Moreover, we draw the individuals from the comparison group in a way that the establishment-level characteristics – sector structure, establishment size, location in East/West Germany – are identical to those of the mass layoff sample (see Table A2). Table 1 shows that over the whole period as well as in each of the three decades average quarterly earnings are comparable in size. The number of days in employment per quarter is very similar in both samples. In terms of the outcome variables there appears to be no evidence that the workers who experienced a mass layoff represent a negatively selected sample. Since mass layoffs occur disproportionally often in the manufacturing sector, the share of females is smaller, the fraction of foreigners is larger, and the education levels are lower among those who experienced a mass layoff.

2.2 Construction of the routine-intensity measure

The objective of this paper is to assess whether the degree to which an employee's occupation contains routine components affects how workers can adjust to unexpected job loss against the background of a changing labour market in which routine labour input can increasingly be substituted by machines. We therefore require a measure of occupational routine-intensity. Related studies from the US typically use information on the task contents of occupations provided by the Dictionary of Occupational Titles (DOT) or the Occupational Information Network (O*NET) to construct corresponding measures (see Autor, 2013 for a description of these datasets).[4]

Instead, we use the BIBB-IAB employee survey (*BIBB-IAB-Erwerbstätigenbefragung*), which has been conducted by the Federal Institute for Vocational Education (BIBB) and the Institute for Employment Research (IAB) in the years 1985, 1991 and 1999. These datasets contain detailed information on various job characteristics and cover between 25,000 (1985 wave) and 35,000 (1991, 1999 waves) individuals. This dataset has already been extensively used by previous German studies to construct measures that reflect the share of routine tasks in an occupation (Spitz-Oener, 2006; Antonczyk et al., 2009; Black and Spitz-Oener, 2010). This approach, however, hinges on correctly classifying the tasks contained in the survey as constituting routine or non-routine tasks. Unfortunately, those questions differ strongly between the different survey waves. For example, the 1985 wave contains five tasks that can be classified as routine manual. This number then increases to eight in the 1991 wave, before falling back to two in the last survey. This makes it difficult to construct a time-consistent measure for an occupation's routine-intensity.

We believe it is more straightforward to measure the potential substitutability by machines by focussing on those parts of the production process where machines have a comparative advantage over human labour. As stated by Autor et al. (2003), machines 'rapidly and accurately perform repetitive tasks that are deterministically specified by stored instruction (programs) that designate unambiguously what actions the machine will perform at each contingency to achieve the desired

[3] For each combination of decade, sector, plant size, and East/West-location we draw twice the number of observations compared to the mass layoff sample.

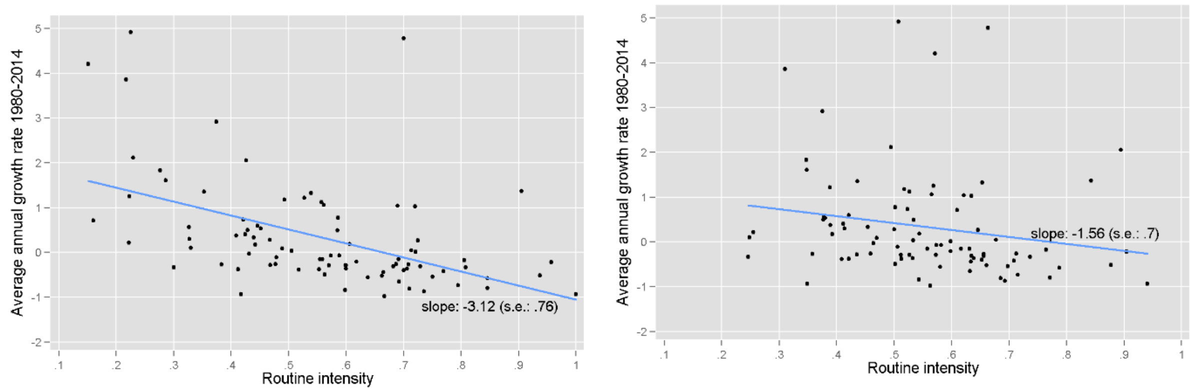
[4] The German equivalent to O*NET is called BERUFENET. Since it is only available from 2011 onwards, it is possible that it only represents the current prevalence of routine components within an occupation, which might actually be the outcome of technological progress and not the situation when people in our analysis selected into occupations or at the time of displacement.

result.’ To capture the notion that machines are effective at repeatedly executing pre-described procedures we make use of the two following items that appear in every survey wave:

1) *Are the contents of your job minutely described by the employer?*
2) *Does the job sequence repeat itself regularly?*

Specifically, we define occupational routine-intensity as the weighted share of workers reporting both items to be the case *‘almost always’* for each of the 83 occupations (*Berufsgruppen*) of the 1988 occupational classification scheme (*Klassifikation der Berufe 1988*).[5] Specifically, we assign each worker the routine-intensity of the occupation performed during the quarter directly preceding the mass layoff. Therefore, we use the measure derived from the 1985 survey for individuals who experienced mass layoff during the decade 1980-89. Analogously, we use the 1991 and 1999 survey for mass layoffs that occurred during the period 1990-99 and 2000-10, respectively. To ensure comparability with other studies, we also replicated the more traditional routine-intensity measure that is based on the share of tasks, which has been used by the previous literature.[6]

Figure 2: Correlation of occupational employment growth and routine-intensity



Panel A: unconditional

Panel B: conditional

Notes: *Panel A shows the correlation of employment growth between 1980 and 2014 and the routine-intensity of the 83 German 2-digit occupations. In Panel B, both variables have been purged of the occupation’s average wage, age, and shares of women and college graduates in 1980. The solid line represents the slope of the regression coefficient. Sources: IEB, BIBB-IAB employee survey.*

Table A3 in the online appendix reports the routine-intensity of each occupation in each survey year. Manufacturing occupations turn out to be particularly routine-intensive: out of the 25 occupations with the highest degree of routine-intensity in each survey year, 21 can be associated with manufacturing. By contrast, technical occupations such as *engineers* or *chemists, physicists and mathematicians* as well as other service occupations such as *teachers* or *journalists, interpreters, librarians* or *management consultants, organisers, chartered accountants* represent large occupations that consistently rank among the bottom 25 in terms of routine-intensity. To see if our definition of routine-intensity is in line with routine-replacing technological change, we use the complete 30% sample of our individual data to plot the average annual employment growth rate of each occupation over the period 1980-2014 against its routine-intensity in 1985. The left panel of Figure 2 shows a clear

[5] We restrict the sample to male and female employees working at least 35 hours per week. Sampling weights are used in the construction of the routine intensity measure. The remaining answer options are *‘often’*, *‘occasionally’*, *‘rarely’* and *‘hardly anytime’*. Table A4 shows that our findings are robust to using the share of workers reporting both items to be the case either *‘almost always’* or *‘often’*. We exclude the group *‘Other occupations’* (*Andere Arbeitskräfte*).

[6] We show in section 4.5 that comparable results are obtained when using the task-based measure of routine intensity.

negative relationship. This is not due to adverse selection of workers in jobs with a high routine-intensity measure. For the right panel, we additionally control for observable characteristics of the workers in each occupation and find a similarly negative relationship.

Analogous to Table 1, we show descriptive statistics of the routine-intensity measure for individuals who experienced a mass layoff and compare them with the corresponding values for a randomly chosen group of workers who did not experience such an event. Table 2 shows that average routine-intensity has a similar size in both groups in each decade and that it decreases over time. We conclude, that, as was the case for the three outcome variables, the employees in the mass layoff sample do not represent a negatively selected sample characterised by unusually high levels of routine-intensity.

Table 2: Worker characteristics (routine-intensity)

		1980-1989		**1990-1999**		**2000-2010**		**1980-2010**
	ML	Comparison	ML	Comparison	ML	Comparison	ML	Comparison
Routine-intensity	13.91	13.19	13.20	12.79	12.08	12.07	13.04	12.67
	(11.63)	(11.29)	(12.43)	(11.70)	(11.31)	(11.42)	(11.88)	(11.50)
Observations	86,310	172,620	125,942	251,884	100,382	200,764	312,634	625,268

Notes: The table shows mean values of routine-intensity as well as the corresponding standard deviations. The columns 'ML' show the values for those workers who experienced a mass layoff (measured at the quarter directly preceding the mass layoff). The columns 'Comparison' show the values for a randomly chosen group of workers who did not experience mass layoff, but who satisfy the same conditions as the workers in the mass layoff sample (e.g. age and minimum level of tenure). Sources: IEB, BIBB-IAB employee survey.

3 Empirical strategy

In a first step, we estimate the effects that a mass layoff has on individual labour market outcomes. For this purpose we employ an event-study approach, which is commonly used in the mass layoff literature (see Schmidheiny and Siegloch, 2019 for a discussion of event-study approaches). Specifically, we use the following difference-in-differences model:

$$y_{it} = \sum_{k=-12,k\neq-1}^{24} \delta_k\, I(t = t' + k) + \varphi_t + \alpha_i + u_{it} \tag{1}$$

The dependent variable y_{it} represents an outcome variable of individual *i* during quarter *t:* quarterly earnings, number of days in employment per quarter, average daily wage. While these outcomes are often measured in logarithmic form, doing so would cause problems with quarters where an individual is not employed and hence receives zero earnings, possibly endogenously due to difficulties in adjusting to the layoff. Instead we measure each outcome as a fraction of the individual's average outcome during the 12 quarters preceding the mass layoff, which also allows for an interpretation in relative terms.

$I(t = t' + k)$ stands for a set of time-to-event dummies which indicate the timing of quarter *t* relative to the quarter of the mass layoff *t'*. The baseline period is the quarter directly preceding the mass layoff ($k = -1$). The coefficients δ_k provide information about the change in the value of the outcome between quarter *t* and the quarter of the mass layoff. They therefore shed light on the average development of outcomes following the mass layoff as well as on the trends prior to the event. In addition, the model includes a set of quarter fixed effects, which account for unobserved macroeconomic effects. α_i represent individual fixed effects that allow us to control for unobserved, time-invariant worker characteristics and u_{it} is a random error term.

One might also want to control for individual characteristics of workers and the characteristics of their employers, all measured in the quarter prior to the event. However, these variables would all be perfectly multicollinear with the individual-specific fixed effects and are therefore already accounted for. We nonetheless show that the results from an alternative model in which the fixed effects are replaced by additional individual-level and establishment-level variables that are measured at the time of the mass layoff are similar to the results presented in the following section.

In order to assess how the effect of job loss varies with the prevalence of routine-intensity in an individual's occupation, we extend the model in Equation (1) by including interactions between our measure of routine-intensity in occupation *o* that was held by individual *i* in the quarter before the mass layoff, RI_o, and the time-to-event dummies:

$$y_{iot} = \sum_{k=-12;k\neq-1}^{24} \left[\gamma_k RI_o \times I(t = t' + k) + \sum\nolimits_{O=1}^{5} \{\delta_k^O I(o \in O) \times I(t = t' + k)\}\right] + \psi_t + \eta_i + v_{iot} \qquad (2)$$

The coefficients γ_k show how a difference in occupational routine-intensity by one percentage point affects the magnitude of the difference in the outcomes between the quarter of the mass layoff (*k = -1*) and the quarter *k*. The corresponding coefficient estimates therefore provide the basis for evaluating whether the effects of job loss are larger among workers in more routine-intensive occupations and whether these effects are persistent.

Our identification strategy builds on comparing the long run effects of a layoff for otherwise identical workers who held similar jobs with routine-intensities that differ only by a small extent. Including individual fixed effects means that individual characteristics are held constant in the cross section. In addition, we want to ensure that each coefficient γ_k is identified by marginal changes in routine-intensity within groups of otherwise similar occupations and not across very different occupations over the entire distribution of the measure of routine-intensity. To this end, we let the coefficients of the time-to-event dummies δ_k^O vary over the 5 aggregate occupation groups (*Berufsbereiche* in the 1988 German occupational classification scheme) that the workers held prior to the layoff. γ_k are thus identified only by the within-variation of *RI* of the 2-digit occupations within each occupational group.

Workers in routine-intensive occupations perhaps would have experienced less favourable labour market outcomes even in the absence of a mass layoff. In such a case γ_k would overestimate the additional costs of displacement for routine-intensive workers. We therefore follow Ahlfeldt et al. (2018) and Monras (2019) and purge our estimates γ_k from diverging long-run trends, which we estimate as the linear extrapolation of the estimated coefficients of γ_k from the pre-event period.

Throughout the remainder of the paper, we summarise the impact of routine-intensity on the cost of displacement in three different ways: (i) the relative impact on the outcome in the quarter immediately after the event, (ii) the average relative impact on the outcome over the six years after the event, and (iii) the total impact (in Euros or employment days) over the full post-event period. We report each of those three measures for a difference in routine-intensity ΔRI by one percentage point and by one within occupation group standard deviation of *RI*. The latter represents a natural difference in *RI* that is independent of the scale of *RI*.[7]

As described in the preceding section, routine-intensity for a given occupation can differ over time. This is the case because individuals experiencing mass layoff during the 1980s are assigned the routine-intensity that is estimated from the 1985 wave of the survey, while the following decades use the surveys from 1991 and 1999, respectively. However, since the identification of the effects only relies on the degree of routine-intensity of the occupation a worker held at the time of the mass layoff, estimation is not confounded by changes in routine-intensity over time. In fact, the results are robust

[7] See section A2 in the supplementary online appendix for a detailed description on how we purge our results from long-run trends, obtain the three summary measures, and obtain the within-occupation-group standard deviation of *RI*.

to using the routine-intensity values from a single survey for all decades as shown in Panel B of Table A4.

4 Results

4.1 Effects of mass layoffs

This subsection illustrates the impact of experiencing a mass layoff. Table 3 shows that experiencing a mass layoff has severe immediate consequences for all labour market outcomes considered in this paper. During the first quarter after the mass layoff average earnings are lower by almost 30% compared to the quarter preceding the event. The change in employment is even larger with a fall by 32%, while average daily wages are lower by 24%.

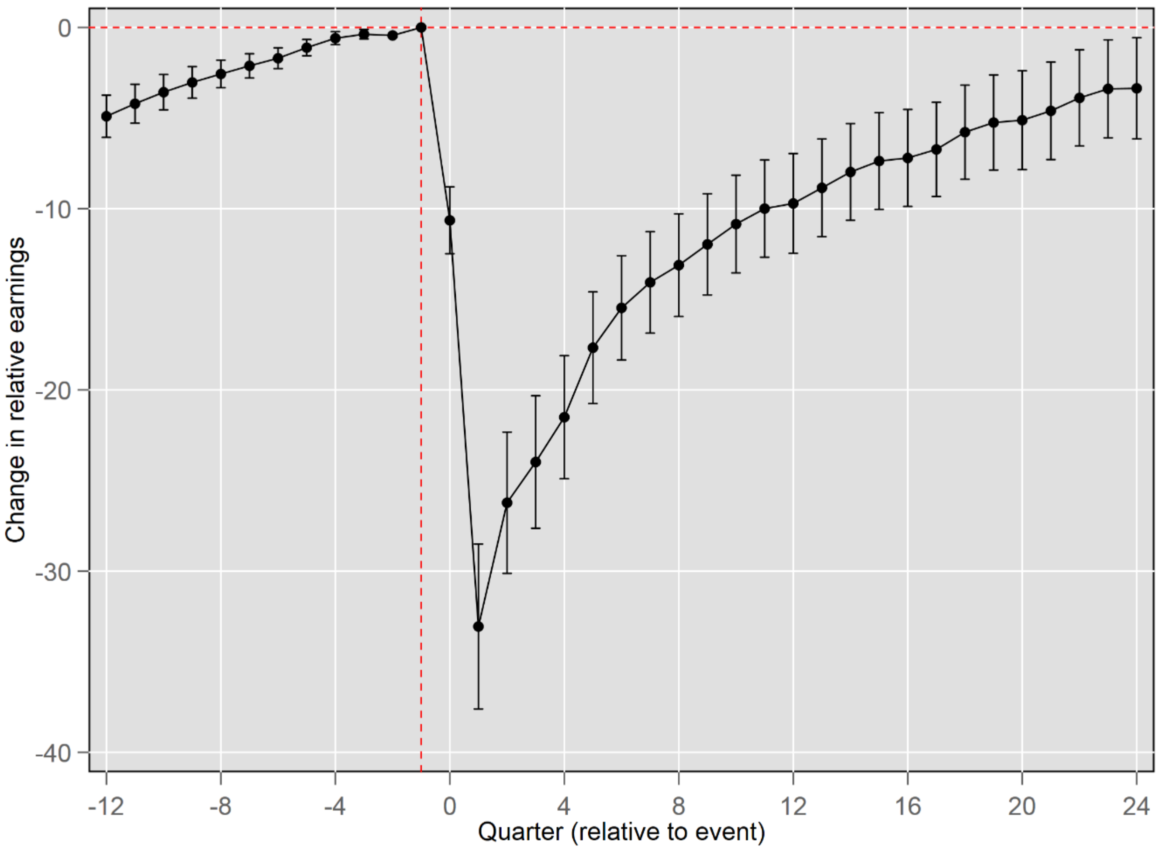
Table 3: Comparing outcomes immediately before and after the mass layoff

	(1)	**(2)**	**(3)**
Outcome	Quarter before mass layoff (k = -1)	Quarter after mass layoff (k = 1)	% change
Earnings (quarterly)	10,119.61	7,212.21	-28.73
Days in employment (quarterly)	91.51	62.39	-31.82
Average daily wage	110.59	83.99	-24.05

Notes: The table shows the average values of the outcome variables for the quarters directly preceding and following the mass layoff as well as the percentage change in these values. Source: IEB.

The long-run effects of experiencing a mass layoff can be assessed by estimating Equation (1) using relative earnings (measured as a fraction of the individual's average earnings before the mass layoff) as the dependent variable. Figure 3 shows the estimated coefficients of the time-to-event dummies. The size of these estimates increases during the period before the mass layoff indicating real earnings growth. However, the mass layoff brings about a break in this development. Following a sharp break right after the event, relative earnings start to increase but remain persistently smaller than the earnings level before the mass layoff.

Figure 3: The impact of mass layoffs on relative earnings



Notes: *Estimates of time-to-event dummies from a regression of relative earnings that also controls for individual fixed effects and quarter dummies. Coefficient estimates of the time-to-event dummies are relative to quarter directly preceding the mass layoff. Vertical bars indicate the estimated 95% confidence interval based on standard errors that are clustered at the level of 83 occupations. Source: IEB.*

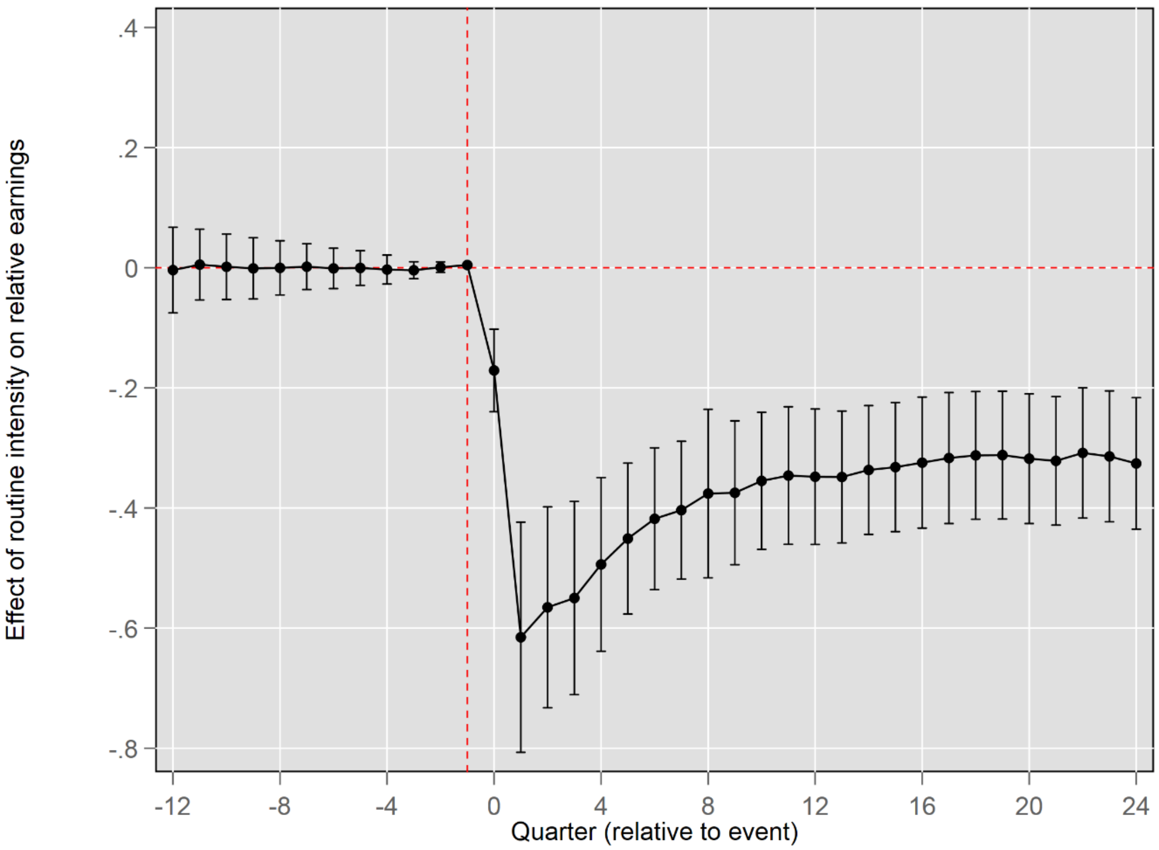
Figure 1 in the introduction was created in the same way as Figure 3, but separately for workers initially employed in occupations from the first and the fourth quarter of the routine-intensity distribution. This figure already suggested that the adjustment to job loss varies with the degree of routine-intensity. While the profile of earnings growth was quite similar in the period before the mass layoff, the initial earnings drop is considerably larger and more persistent for workers from high-routine occupations. Panels B and C of Table A5 show that this stems from a larger initial drop and slower adjustment in both employment and wages.

However, one might object that workers in occupations at the extremes of the distribution of routine-intensity are not comparable in many ways. In particular, workers might self-select into occupations with different routine-intensities according to (unobserved) characteristics that also determine their labour market outcomes after the layoff. Our baseline results therefore stem from Equation (2), where we interact the time-to-event indicators with a continuous measure of routine-intensity and control for occupational group-specific developments.

4.2 Baseline specification

Figure A5 in the appendix shows the estimated coefficients of the interaction terms of the time-to-event indicators with our continuous measure of routine-intensity. The interpretation of these estimates is by how many percentage points the earnings loss in the *k*th quarter (relative to the quarter before the layoff) is magnified due to a one percentage point increase in routine-intensity. Alternatively, these coefficients indicate the proportional difference in the change in earnings in quarter *k* between two workers whose routine-intensity differs by one percentage point. None of the coefficients differs significantly from zero prior to the event. However, there is a clear linear downwards trend. This indicates that workers in more routine-intensive jobs experienced slightly smaller real wage growth compared to workers in less routine-intensive jobs. Extrapolating this trend to the right, as shown by the dashed line, suggests that workers in more routine-intensive jobs would experience a decline in earnings even if they had not experienced a mass layoff. We take this development into consideration in the estimation of the effects of routine-intensity on the outcomes by linearly extrapolating the pre-event trend and then calculating the effect of routine-intensity as the difference between the estimated coefficient of the interaction term and the extrapolated pre-event trend.[8]

Figure 4: Effect of routine-intensity on relative earnings



<u>Notes:</u> Units of observation are individual-level relative earnings within a quarter. Relative earnings are the ratio of the earnings during a specific quarter and the average earnings level during the period before the mass layoff. Quarters are measured relative to the event of the mass layoff and indicate periods before (negative values) and after the layoff (positive values). The graph shows the estimated coefficients of the interactions between the treatment variable and the time-to-event dummies. The estimates have been purged of a linear trend in the coefficient estimates of the period before the mass layoff. The unadjusted estimates are available in Figure A5. *Vertical bars indicate the estimated 95% confidence interval. Standard errors are clustered at the level of 83 occupations. Sources: IEB, BIBB-IAB employee survey.*

Figure 4 shows the so-adjusted estimates. The pattern looks somewhat similar to the results for the overall income losses after experiencing a mass layoff. After the layoff, all interaction terms have large negative estimated coefficients, which does not change even after correcting for differences in pre-event trends. The strong earnings decline in the quarter after the layoff is magnified by 0.6 percentage

[8] This correction, however, is relatively small. The estimated interaction terms are predicted to decrease by approximately 0.0037 units per quarter.

points for workers who prior to the layoff that used to be employed in an occupation for which the routine-intensity is larger by one percentage point. This amounts to around two percent of the overall earnings decline. The routine-penalty declines over time but remains substantial throughout the observation period and levels off at around 0.3 percentage points.

Table 4: Effects of routine-intensity on labour market outcomes

ΔRI	**(1)** Relative change (k = 1)	**(2)** Relative change (average)	**(3)** Average absolute value (before ML)	**(4)** Absolute change (cumulative)
	Panel A – Earnings (quarterly)			
Percentage point	-0.62	-0.38	10,052.46	-925.23
Within-standard deviation (5.00 pp)	-3.08	-1.91	10,052.46	-4,628.49
	Panel B – Days in employment (quarterly)			
Percentage point	-0.62	-0.33	91.31	-7.21
Within-standard deviation (5.00 pp)	-3.10	-1.65	91.31	-36.09
	Panel C – Average daily wage			
Percentage point	-0.08	-0.10	110.09	
Within-standard deviation (5.00 pp)	-0.39	-0.49	110.09	

Notes: The table shows different marginal effects of routine-intensity on each of the relative outcome variables evaluated for changes in routine-intensity by one percentage point or by one within-standard deviation. The within-standard deviation refers to the standard deviation of the residuals that are derived from a regression of the routine-intensity variable on fixed effects for 32 occupational groups ('Berufsabschnitte'). Column (1) contains the marginal effect in the first quarter after the mass layoff, while Column (2) shows the average marginal effect over the whole period after the mass layoff. Column (3) shows the average value of earnings, employment duration and average wages during the period before the mass layoff. Column (4) shows the absolute cumulative marginal effect over the whole period following the mass layoff and is computed for a worker with an average value of earnings during the pre-event period. Sources: IEB, BIBB-IAB employee survey.

Panel A of Table 4 quantifies the difference in the change in earnings due to a difference in the degree of initial routine-intensity in three different ways. Column (1) shows that a difference in routine-intensity by one percentage point on average further reduces the earnings in the first quarter after the mass layoff by approximately 0.6 percentage points relative to average earnings before the layoff, ceteris paribus. We also show the effects that result from a change in routine-intensity by one within-occupational group standard deviation after purging the routine-intensity variable from the variation that exists between 32 broader occupational groups. For the first quarter, the additional earnings decline due to a difference in routine-intensity by one such standard deviation, which amounts to approximately 5 percentage points, is a further reduction in earnings by 3.1 percentage points, ceteris paribus.

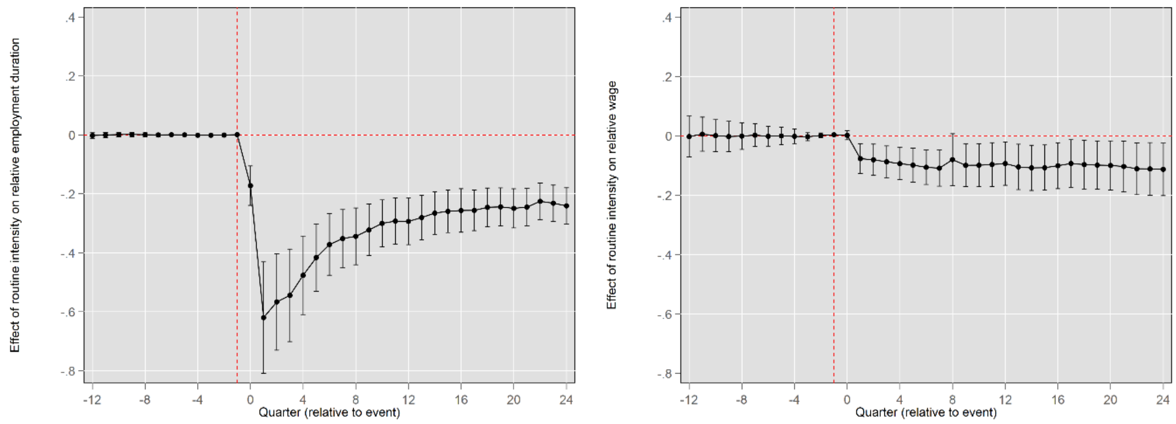
As illustrated by Figure 4, the negative impact of routine-intensity on subsequent earnings subsides with time. Reflecting this pattern, the average proportional effect amounts to 0.4 percentage points for an increase in routine-intensity by one percentage point and to 1.9 percentage points in the case of an increase by one within standard deviation. In order to obtain an intuition for the absolute magnitude of the effects, we last calculate the expected changes in earnings for a worker with the mean level of earnings (displayed in column 3) for each of the quarters of the post-layoff period. Column (4) contains the sum of these quarter-specific changes over the six years after the event. A difference in routine-intensity by one percentage point leads to a cumulated earnings loss of approximately 925 Euros, while the additional reduction in earnings for a change by one standard deviation amounts to 4,600 Euros.

4.3 Decomposition

The previous sub-section showed that otherwise identical workers, on average, suffer a larger drop in earnings if they were initially employed in more routine-intensive occupations. This might be explained by workers in more routine-intensive occupations being more likely to switch to lower paid occupations as suggested by Cortes (2016). However, while this literature usually assumes instantaneous adjustment, another explanation is that many displaced workers find a new job only after a period of unemployment. This period might be longer for workers laid-off in more routine-intensive occupations because employment in these occupations has been on the decline as shown in Figure 2. Since quarterly earnings are the product of days in employment per quarter and average daily earnings, we now discriminate between these channels.

In order to do so, we estimate Equation (2) separately for the number of days in employment per quarter and the average daily wage per quarter, both normalized by the worker's averages before the layoff.[9] Figure 5 shows the estimated coefficients of the interaction term between time-to-event dummies and the routine-intensity for both outcome variables which have been linearly adjusted for the pre-event trend. In the case of days in employment, the pattern of the estimates largely resembles those for the relative earnings, whereas the effect on relative wages appear relatively small and do not vary much over time. Specifically, we find an increase in routine-intensity by one percentage point further reduces days in employment per quarter by 0.6 percentage points relative to the average number of days during the quarters preceding the layoff. The corresponding effect for the relative wage is a reduction by an additional 0.08 percentage points.

Figure 5: Effect of routine-intensity on the relative employment duration and relative average wage



Notes: *See Figure 4. Units of observation are an individual worker's days in employment per quarter and the average daily wage, respectively. Unadjusted estimates are available in Figure A6 and Figure A7. Sources: IEB, BIBB-IAB employee survey.*

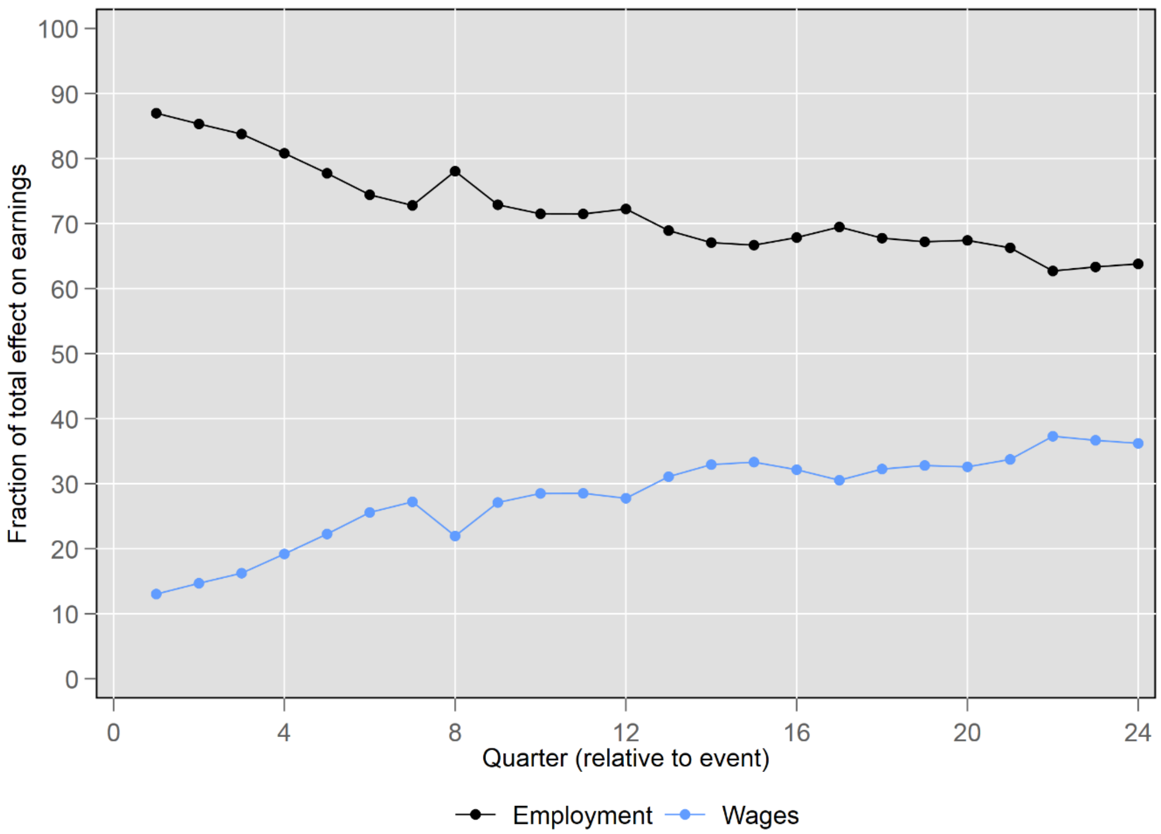
[9] The coefficients from both models sum up approximately to the coefficients of the model of log earnings. The sum is not exactly equal to the baseline coefficients since we add 1 to the outcomes to prevent quarters with zero earnings or employment days to be omitted from the analysis.

To assess the relative importance of these two channels, we compute the total differential in relative earnings that results from an increase in routine-intensity by one percentage point which works through a change in employment and wages. To evaluate the magnitude of the effect we compute it at the mean value of employment duration and average wages during the period before the mass layoff:

$$\frac{\partial(E_{iot}/\bar{E}_{io})}{\partial RI}\bar{E}_{io} \approx \left[\frac{\partial(L_{iot}/\bar{L}_{io})}{\partial RI}\bar{L}_{io}\right]\bar{W}_{io} + \left[\frac{\partial(W_{iot}/\bar{W}_{io})}{\partial RI}\bar{W}_{io}\right]\bar{L}_{io} \qquad (3)$$

The first part on the right hand side of Equation (3) represents the effect of routine-intensity that can be ascribed to changes in employment duration, while the second part captures the corresponding effect due to changes in wages. In the first quarter, almost 90% of the reduction in earnings, that are brought about by a higher degree of routine-intensity, is due to non-employment, while only 10% are the result of earnings lower wages. Over time, the fraction of the earnings effect that can be ascribed to wages increases to about one third as shown in Figure 6. Overall, these results provide evidence that the larger costs of job loss associated with a higher degree of routine-intensity are due to a large extent to non-employment. This contradicts the finding of Bachmann et al. (2019), who find that workers in more routine-intensive jobs are more likely to become unemployed but do not find an effect on the duration of unemployment. This difference might stem from the fact that we focus on a specific group on routine workers – those who experienced a mass layoff – to account for selection issues.

Figure 6: Decomposition of earnings effect of routine-intensity

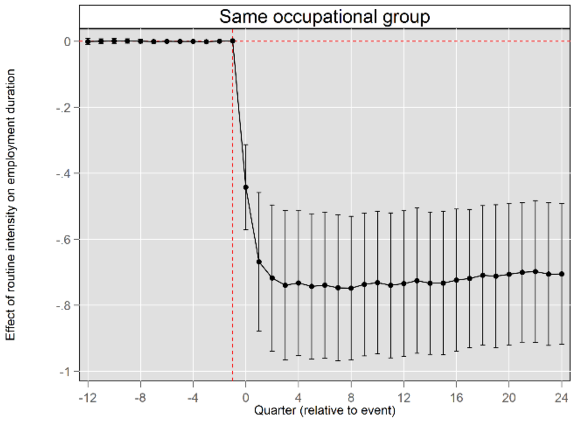


__Notes:__ Computed for mean values during the period before the mass layoff. Sources: IEB, BIBB-IAB employee survey.

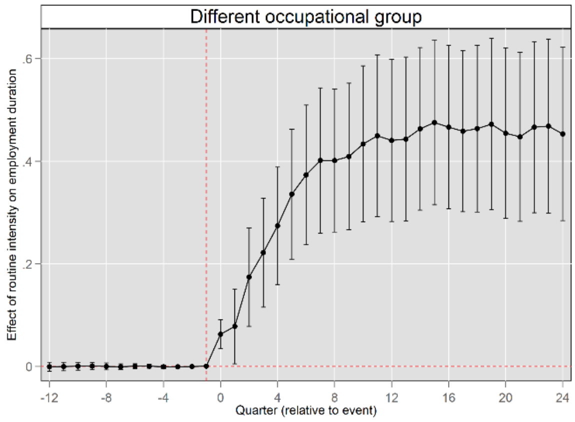
4.4 Subsequent transitions into employment

We have shown that mass layoffs lead to large and persistent reductions in earnings for all workers, but that for workers who used to be employed in routine-intensive occupations, the costs of job loss are more severe and more persistent. In this sub-section we aim to analyse in more detail how subsequent employment biographies are shaped by the routine-intensity of the previous occupation. After having been employed in an occupation for a certain time, workers possess a specific human capital either acquired by on-the-job learning or because they needed to have certain skills in order to get their specific job in the first place. Previous evidence has shown that displaced workers are particularly at risk of losing this specific human capital because they are often forced to switch to different occupations that either use different skills compared to the previous occupation or the same skills but by a lower intensity (Robinson, 2018). For more routine-intensive occupations, the additional problem is that the demand for them decreased constantly during the past decades, as shown in Figure 2, which further increases the likelihood to involuntarily switch to a different occupation. While job protection legislation might have shielded these workers to a certain degree on the job, they are exposed to this development after displacement and when searching for a new job.

Figure 7: Effects on the duration of employment by same vs. different occupational group



Panel A: Same occupational group



Panel B: Different occupational group

Notes: See Figure 4. For the pre-event period, the dependent variable is given by the number of days in employment per quarter; during the post-event period the dependent variable takes on non-zero values only in those quarters during which a worker is employed in the same occupation as (Panel A) or a different occupation than (Panel B) during the quarter directly preceding the mass layoff. Sources: IEB, BIBB-IAB employee survey.

To shed further light on the adjustment processes of laid-off workers in times of technological change, we assess the impact of routine-intensity on the ability of taking up employment in higher-quality jobs – as measured by average daily wages – as well as on occupational and regional mobility. To this end, we estimate several variations on Equation (2). For the first variation, we use we differentiate quarterly employment during the post-event period according to whether a worker is employed in the same or in a different occupational group as compared to the quarter before the layoff.[10] For example, when we are interested in the effect of routine-intensity on employment chances in the worker's initial occupational group, we set the employment duration to zero for all post-layoff observations where a worker is either unemployed or employed in a different occupational group. This way, the coefficients of the interaction terms that belong to post-layoff quarters add up to the overall effect on the number

[10] We use the six values of the *Berufsbereiche* in the 1988 German occupational classification scheme.

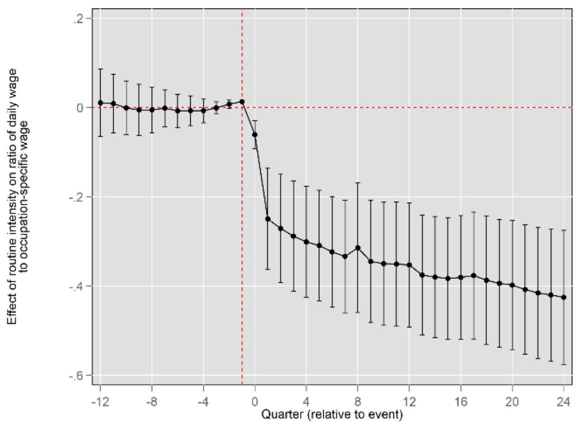
of days in employment per quarter. In the same way, we differentiate employment in the same county as opposed to a different county.[11]

Panel A of Figure 7 shows that the workers who previously held a more routine-intensive occupation are less likely to return to this or a similar occupation after the layoff. This corroborates the hypothesis that in times of declining demand for routine occupations, the job-specific skills of workers in routine-intensive jobs lose value immediately in the case of a layoff. As Panel B shows, the more routine-intensive the previous job was, the more likely it is that subsequent employment will be in a different occupation.

Having established that more routine-intensive workers are more likely to switch to a different occupation, it is also interesting to consider the quality of the new jobs. This quality has two dimensions: first, workers could switch into an occupation with a higher or lower average wage compared to their previous occupation. Second, they could enter the new occupation at a specific part of the wage distribution within the new occupation. The former is difficult to analyse: since routine-intensive occupations tend to be at the lower end of the wage distribution in Germany, workers leaving those occupations are more likely to move to an on average better paid occupations by definition. We therefore concentrate on the latter and measure the quality of the job as the individual's daily wage relative to the average wage of incumbent workers in this occupation.

The coefficients in Figure 8 provide two interesting insights. First, the coefficients are significantly negative after the event. One would expect most job switchers to arrive at the bottom of the wage distribution of their new occupation because of their lack of specific human capital, irrespective of their old job's routine-intensity. However, this effect is magnified by routine-intensity: Routine workers fare worse relative to incumbent workers compared to those who switch out of less routine-intensive occupations. The second notable result is that all coefficients before the event are virtually zero. This indicates that the more routine-intensive workers in the mass layoff sample are no negative selection because they were similarly paid to workers in the comparison group. This lends credence to our empirical strategy.

Figure 8: Effects on own wage relative to occupation-specific mean wage

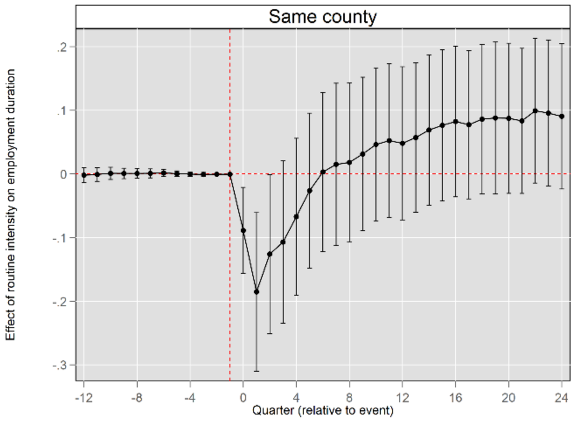


Notes: See Figure 4. The dependent variable is defined as worker-specific average daily wages relative to the daily wages that are paid on average in the occupation that the worker is employed in at time t. Occupation-specific average wages are computed from a comparison sample of workers as described in Section 2.1. Sources: IEB, BIBB-IAB employee survey.

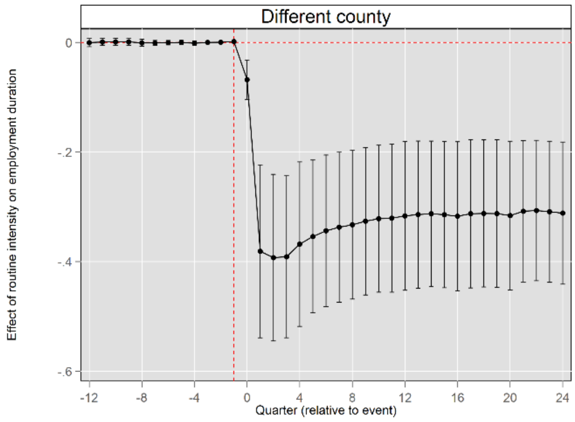
[11] Similar results are obtained when using the 32 values of the *Berufsabschnitte*. Likewise, comparable patterns emerge when labour-market regions are used instead of counties. Results are available upon request.

Finally, we look at regional mobility as a possible adjustment mechanism to a mass layoff. Figure 9 shows that a higher degree of routine-intensity has a negative effect on subsequent employment in a different county. While employment in routine-intensive occupations is associated with subsequently finding employment in a different occupation, it is also related to lower regional mobility. Both findings might be related: Due to the mass layoff, there might be an oversupply of job seekers searching for a new job in a certain occupation. Regional mobility might increase an individual's probability of finding an adequate new job and at the same time reduce the competition among the remaining job seekers.

Figure 9: Effects on the duration of employment by same vs. different county



Panel A: Same county



Panel B: Different county

Notes: *See Figure 4. For the pre-event period, the dependent variable is given by the number of days in employment per quarter; during the post-event period the dependent variable takes on non-zero values only in quarter during which a worker is employed in the same county as (Panel A) or a different county than (Panel B) during the quarter directly preceding the mass layoff. Sources: IEB, BIBB-IAB employee survey.*

4.5 Effect heterogeneity and robustness checks

In this paper, we deviate from the traditional way to construct a measure for the routine-intensity of an occupation from data of the BIBB-IAB-*Erwerbstätigenbefragung* used in previous studies (e.g. Spitz-Oener, 2006; Antonczyk et al., 2009; Black and Spitz-Oener, 2010). We argue that the design of the surveys prohibits a time-consistent measurement of routine-intensity. To ensure comparability with other studies, and to demonstrate that our results do not hinge on this decision, we also construct a routine-intensity measure that is based on the share of tasks in the survey that can be classified as routine. We proceed to compare the positions of the 83 occupations in the distribution of the routine-intensity variable that is used in this paper and the task-based measure.

Figure A1 shows that there is a considerable positive correlation between the measure of routine-intensity used in this paper and the task-based measure for each of the three decades under study. This is especially the case at the ends of the distribution suggesting that both approaches identify similar of occupations as being the most and least routine-intensive. The correlation coefficient between our measure and the traditional one is 0.6.

Next, we replicate the empirical analysis of equation (2) using the traditional task-based routine-intensity variable. The results of this robustness check are reported in Table 5. Again, we measure the additional costs of displacement due to a difference in routine-intensity in three ways: Directly after the event, on average over the entire post-event period and the cumulative costs. Since the variation of this routine-measure differs from our routine-intensity, we again compute the within-occupational group standard deviation to evaluate those effects. The effects of a one within-standard deviation difference in routine-intensity are comparable to our baseline results in Table 4. We therefore conclude that our results do not stem from the choice of how to measure routine-intensity but rather base on the underlying mechanism that workers in more routine-intensive occupations find it more difficult to adjust to a break in their employment career.[12]

Table 5: Effects of routine-intensity on labour market outcomes using a task-based measure of routine-intensity

ΔRI	(1) Relative change (k = 1)	(2) Relative change (average)	(3) Average absolute value (before ML)	(4) Absolute change (cumulative)
	Panel A – Earnings (quarterly)			
Percentage point	-0.23	-0.17	10,052.46	-421.63
Within-standard deviation (14.46 pp)	-3.26	-2.52	10,052.46	-6,072.18
	Panel B – Days in employment (quarterly)			
Percentage point	-0.22	-0.11	91.31	-2.44
Within-standard deviation (14.46 pp)	-3.13	-1.61	91.31	-35.30
	Panel C – Average daily wage			
Percentage point	-0.04	-0.08		
Within-standard deviation (14.46 pp)	-0.51	-1.11		

Notes: *See Table 4. A task-based measure of routine-intensity is used. Sources: IEB, BIBB-IAB employee survey.*

We are also interested in whether the effects of having been employed in a more routine-intensive occupation prior to a mass layoff varies across specific groups of the population. To analyse this, we split the sample into disjunctive groups and estimate the model of Equation (2) separately for each group. Table 6 shows the variation of the effect of an additional percentage point of routine-intensity of the previous occupation on earnings by different subgroups. The first column again reports the effect of one additional percentage point of routine-intensity on earnings in the quarter after the layoff. To assess the uncertainty of this estimate, we add the standard error of the interaction term in parentheses. Column 2 shows the average effect over the entire post-layoff period in relative terms and column 4 in absolute terms. In column 3, we report the average earnings of the respective group in the quarter before the layoff as a benchmark. In Panel A, workers are distinguished by educational degree. Over the entire post-layoff period, the fall in earnings is largest for workers with vocational training, while routine-intensity does not appear to differentially affect subsequent earnings of high-skilled workers. It is interesting to see that all estimates of the short run effects of routine-intensity are slightly smaller in magnitude. This indicates that the overall effect of -0.6 also reflects some systematic compositional differences in terms of skills. More routine-intensive occupations typically require a lower education and the overall effect stems in part from the fact that less educated people

[12] The corresponding event-study plots can be found in Figure A2, Figure A3 and Figure A4.

have more difficulties finding a new job in general. Column 1 in Panel B shows that proportionally the additional initial earnings reduction is slightly smaller among younger workers, although the difference is not significant. We therefore do not find strong evidence that the negative impact of routine-intensity is concentrated among older workers.

Table 6: Effects of routine-intensity on earnings by population groups

	(1)	(2)	(3)	(4)
Dependent variable: Quarterly earnings relative to average earnings before the mass layoff				
	Relative change (k = 1)	Relative change (average)	Average absolute value (before ML)	Absolute change (cumulative)
Baseline specification	-0.62 (0.10)***	-0.38	10,052.46	-925.23
Panel A – By Education				
Unskilled	-0.32 (0.07)***	-0.17	7,207.35	-299.56
Vocational training	-0.50 (0.11)***	-0.33	9,497.05	-744.96
College degree	-0.01 (0.22)	0.20	21,154.77	1,044.86
Panel B – By age at layoff				
23-29 years	-0.61 (0.10)***	-0.38	7,633.07	-705.24
30-44 years	-0.62 (0.10)***	-0.36	10,330.71	-899.82
45-51 years	-0.57 (0.10)***	-0.40	10,703.76	-1,027.56
Panel C – By decade of mass layoff				
1980-89	-0.78 (0.08)***	-0.31	8,567.81	-652.43
1990-99	-0.49 (0.12)***	-0.35	9,859.79	-819.85
2000-10	-0.68 (0.15)***	-0.48	11,570.72	-1,348.20
Panel D – By sector of mass layoff				
Manufacturing	-0.61 (0.07)***	-0.39	9,775.60	-932.40
Non-Manufacturing	-0.53 (0.25)**	-0.32	10,561.98	-814.86
Panel E – Urban vs. rural				
Urban	-0.66 (0.08)***	-0.40	10,642.07	-1,035.57
Rural	-0.47 (0.15)***	-0.31	7,929.22	-582.42
Panel F – By share of the workforce laid off				
Less than 90%	-0.64 (0.09)***	-0.37	10,162.22	-913.60
More than 90%	-0.56 (0.13)***	-0.38	9,845.82	-905.52

*Notes: See Table 4. Marginal effects are computed for different sub-groups. Column (1) contains standard errors in parentheses and significance levels: *** (0.01), ** (0.05), * (0.10). Sources: IEB, BIBB-IAB employee survey.*

Splitting the sample also allows us to check the robustness of our results in several ways. The results in Panel C show that the effect of routine-intensity is slightly smaller for mass layoffs that took place in the 1990s. More interestingly, the short-run effect is considerably larger in the manufacturing sector, as can be seen in Panel D. Most routine-intensive occupations are related to manufacturing (see Table A3). Workers laid off in this sector have the problem of a devaluation of their human capital because of technological change and the general trend of structural change of employment from the manufacturing to the service sector. However, the overall results are not driven exclusively by mass layoffs in manufacturing since significant effects are also found for workers employed in non-manufacturing establishments. In Panel E, we distinguish between urban and rural counties and find that the effect of routine-intensity is larger for workers in urban than in rural areas. Finally, one objection against our identification strategy might be that our definition of mass layoffs comprises closures of establishments as well as events in which establishments continue to exist but lay off only a fraction of their workforce. To check if this affects our results, we split the sample by whether an establishment laid off more or less than 90% of its workforce. In Panel F shows that there are only marginal differences between these cases.

Finally, we run a number of additional robustness checks and report the results in Table A4. While the baseline specification employs worker fixed effects in order to control for the effects of individual- and establishment-level characteristics from the quarter preceding the mass layoff (as well as unobservable time-invariant influences), Panel A shows the results from a specification that uses these variables instead of the fixed effects. The estimated effects are qualitatively similar, albeit slightly smaller as suggested by the smaller absolute change shown in column 4. The results in Panel B derive from the same empirical model as specified in Equation (2), but are based on different forms of the routine-intensity measure. First, we assess the sensitivity of the results by extending the definition of routine-intensity to the share of workers in an occupation reporting both items to be the case 'almost always' or 'often'. As expected, including workers for whom routines are not as common reduces the magnitude of the effects, although the former remain negative. Finally, we use routine-intensity measures that rely on a single wave of the 'employee survey'. The estimated effects are negative in each case. However, the magnitude of the absolute change in column 4 is largest if the data from the 1985 survey is used and smallest for the 1991 survey suggesting that not taking into account changes in occupational job contents results in an over- or underestimation of the effects.

5 Conclusion

There is a broad consensus that technological change is routine-biased and has led to the secular decline of routine-intensive jobs. This paper assesses how this secular trend affects individual workers. We argue that in a country like Germany, labour market institutions shield workers to a certain degree from the immediate effects of technological change. If a firm wants to replace employees in routine-intensive occupations by machines or by different workers specialized in less routine-intensive tasks, job protection laws or works councils might influence the selection process. We hence concentrate on a group of individuals that are particularly vulnerable: workers who lost their job during a mass layoff event. Those workers are forced by exogenous reasons to adjust to both, the layoff itself and the consequences of technological change.

Our findings on the overall costs of experiencing a mass layoff are in line with the extant literature. However, even comparing only similar workers in the same occupation group, we find that workers who worked in a routine-intensive occupation prior to the layoff have more difficulties to recover from the layoff. With each additional standard deviation of routine-intensity, the total earnings losses over the subsequent six years increase on average by 4,628 Euros. Initially, almost 90 percent of this additional loss stems from a reduced time in employment, while the rest stems from employment at a lower wage. This suggests that there is a modest additional disadvantage for routine workers on top of the wage reduction experienced by all workers who lost their previous job due to a mass layoff. However, a more important mechanism is that the time it takes to find an adequate new job appears to increase with the routine-intensity of the previous job. This highlights the importance of unemployment in the adjustment to technological change. Transitions to new employment appear not to be as smooth as often assumed by the theoretical literature.

Our analysis provides additional insights on the quality of job switches of routine workers. Workers who previously held a more routine-intensive occupation are less likely to find a new job in the same or similar occupation and are more likely to end up at the bottom of the wage distribution of their new occupation. This is in line with the literature on the mobility of routine workers into non-routine occupations and on the loss of specific human capital.

These results highlight an additional channel of how routine-biased technological change affects the labour market on the intensive margin. Once confronted with an exogenous shock to their careers, workers in routine-intensive occupations face persistently worse labour market outcomes for the rest or their working life. This fosters income inequality since routine-intensive jobs are typically located at the lower part of the wage distribution – at least in Germany. Labour market policies targeted at routine workers should thus aim to improve the employability of those workers either at their original workplace even before a possible layoff or in different firms.

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Supplementary Online Appendix

A1 Identification of mass layoffs

We use the IAB Establishment History Panel (BHP, version 7516 v1) to identify plants that experienced a mass layoff. This dataset includes annual information on the number of workers subject to social security on 30 June of a given year for all establishments in Germany.[13]

The panel structure of the BHP allows us to identify those establishments that initially have a sufficiently large and stable workforce which then contracts sharply from one year to the next and does not recover to its initial level in the following years. Specifically, for an establishment to be defined as having experienced a mass layoff, we impose the conditions that there must have been at least 50 workers employed on 30 June of year t and the size of the workforce must not have been below 80 percent or above 120 percent of that level in the two preceding years. Between the years t and t+1 the establishment's workforce has to fall by between 30 and 100 percent and must not recover by more than 50 percent of the initial drop within the next two years.[14] Since the data in the BHP is at the establishment level, it is possible that large changes in the size of the workforce represent restructuring within multi-establishment firms rather than genuine mass layoffs. For this reason, we adopt the approach of Hethey-Maier and Schmieder (2010) and remove those establishments from the sample where the drop in employment is the result of restructuring rather than a genuine mass layoff.

Our dataset contains 9,230 establishments that experienced mass layoff between 1980 and 2010 and a total of 312,634 affected workers. Table A2 contains information on different characteristics of these establishments that refer to the quarter before the mass layoff. The number of establishments and workers is larger during the last two decades reflecting an increase in the workforce following the German re-unification. Initially, mass layoffs occur predominantly in manufacturing with 66% of establishments in the decade 1980-89 and 73% of workers being accounted for by that sector.[15] Though manufacturing remains the largest single sector in terms of mass layoffs, these shares have fallen to 43% and 56%, respectively, in the last decade. At the same time, mass layoffs have become more common in the service sectors with increases in *K – Real estate, renting and business activities*, *I – Transport, storage and communication* as well as *G – Wholesale and retail trade*. Taken together, these sectors account for 49% of the affected establishments and 37% of workers during the decade 2000-2010. More than half of the establishments in the sample employ between 50 and 99 workers, while more than 80% have workforces below 199 employees. The differences between the size groups are considerably smaller in terms of employment shares. During the second and third decade, less than one fifth of establishments are located in East Germany.

A2 Calculation of Effect of Routine-intensity

This section describes how we compute the effects of routine-intensity on the different outcome variables. In a first step, we remove any long-run outcome trends that may differ between occupations that are more or less routine-intensive. This is done by linearly extrapolating the estimated interaction terms between the routine-intensity variable and the time-to-event dummies from the time period

[13] Establishments must have at least one worker subject to social security contributions or, from 1999 onwards, at least one marginally employed workers. See Spengler (2008) for further details on the BHP.

[14] As discussed in section 4.5, the results of the empirical analysis are robust to restricting the sample to those establishments in which the mass layoff is very close to a complete closure.

[15] Sector definitions follow the *German Classification of Economic Activities (edition 1993)*. We do not consider mass layoffs that occurred in sector *O – Other community, social and personal service activities*.

before the mass layoff (see Ahlfeldt et al., 2018 and Monras, 2019 for further examples of this procedure). Specifically, we regress the coefficient estimates of γ_k on a constant and a linear trend:

$$\hat{\gamma}_{k|k\leq-1} = \pi_0 + \pi_1 k + w_k \tag{4}$$

The estimated coefficients of the above equation form the basis for computing the counterfactual for the post-event period, which we subtract from the event study estimates:

$$\hat{\tau}_{k|k>-1} = \hat{\gamma}_k - (\hat{\pi}_0 + \hat{\pi}_1 k) \tag{5}$$

Based on this adjustment we compute three types of effects. First, we report the change in the relative outcome during the first quarter after the mass layoff. Second, we compute the average value of this effect over all quarters following the mass layoff, which takes into account the fact that the magnitude of the effects change over time. Next, we use the average value of the outcome variables before the mass layoff to compute an estimate of the absolute change in the outcome for each quarter following the mass layoff. Our third measure is then given by the sum of these quarter-specific effects.

We report each of those three measures for a difference in routine-intensity *ΔRI* by one percentage point. A more natural difference might be the standard deviation of *RI*. Yet, our identification strategy hinges on small differences in *RI* for otherwise comparable workers. We therefore also report each measure for *ΔRI* equal to the within occupation group standard deviation of *RI*. To this end, we first regress *RI* on dummy variables for 32 aggregate occupation groups (*Berufsabschnitte*). Then we use the law of total variance and compute the within occupation group standard deviation as the standard deviation of the residuals from this regression.

A3 Alternative Routine Measure

Section 2.2 describes how occupational routine-intensity is defined in this paper and how a corresponding measure is constructed from the *employee survey*. Since other papers have made use of a task-based measure that is derived from the same dataset, we showed in section 4.5 that the results are robust to using this measure of routine-intensity. In the following we detail the construction of the task-based measure.

After employing the same sample restrictions as outlined in section 2.2, we compute the share of routine tasks for each worker in the sample. Routine tasks consist of routine cognitive and routine manual tasks. Since the list of tasks differs between the surveys, we document how we classify routine tasks in Table A1 (in doing so, we follow Table 1 in Spitz-Oener, 2006 and Table 4 in Antonczyk et al., 2009 as closely as possible). For routine-intensity at the occupational level we compute an hours-adjusted share of routine tasks.

A4 Appendix Tables and Figures

Table A1: Classification of routine tasks

Wave	Routine cognitive tasks	Routine manual tasks
1985	Schreibarbeiten/Schriftverkehr, Formulararbeiten Kalkulieren/berechnen, buchen	Maschinen, Automaten, Anlagen einrichten, einstellen, umrüsten, programmieren Maschinen, Automaten, Anlagen bedienen, steuern, beschicken Anbauen, züchten, hegen; gewinnen/abbauen, fördern Stoffe erzeugen, ausformen; verarbeiten/bearbeiten, kochen Bauen/ausbauen, installieren, montieren
1991	Schreibarbeiten, Schriftverkehr, Formulararbeiten Kalkulieren, berechnen, buchen	Maschinen/Anlagen einrichten, einstellen usw. Maschinen/Anlagen bedienen, steuern usw. Pflanzen anbauen/Tiere züchten Rohstoffe gewinnen, abbauen, fördern Stoffe erzeugen, verarbeiten, Speisen bereiten Gebäude/Anlagen/Geräte bauen, montieren usw. Packen, verladen, versenden, zustellen Sortieren, ablegen, auszeichnen usw.
1999	Messen, Prüfen, Qualitätskontrolle	Überwachen, Steuern von Maschinen, Anlagen, technischen Prozessen Herstellen, Produzieren von Waren und Gütern

Source: BIBB-IAB employee survey.

Table A2: Establishment characteristics

Panel A – Establishment level	1980-1989		1990-1999		2000-2010		1980-2010	
	mean	sd	mean	sd	mean	sd	mean	sd
D – Manufacturing	65.80	(47.45)	58.89	(49.21)	43.21	(49.55)	55.14	(49.74)
E – Electricity, gas, and water supply	0.30	(5.46)	0.69	(8.25)	0.40	(6.32)	0.49	(6.97)
F – Construction	2.43	(15.41)	1.989	(13.63)	1.88	(13.59)	2.03	(14.09)
G – Wholesale and resale trade	19.17	(39.37)	18.76	(39.04)	22.09	(41.49)	20.03	(40.03)
H – Hotels and restaurants	1.15	(10.68)	1.81	(13.33)	2.65	(16.07)	1.94	(13.79)
I – Transport, storage and communication	4.06	(19.73)	7.73	(26.72)	9.65	(29.54)	7.48	(26.30)
J – Financial intermediation	1.49	(12.14)	1.76	(13.13)	2.38	(15.23)	1.91	(13.68)
K – Real estate, renting and business activities	5.59	(22.98)	8.48	(27.85)	17.74	(38.20)	11.00	(31.29)
50-99 employees	56.49	(49.59)	57.43	(49.45)	61.69	(48.62)	58.69	(49.24)
100-199 employees	26.43	(44.11)	26.58	(44.18)	25.14	(43.39)	26.03	(43.88)
200-499 employees	13.88	(34.58)	12.10	(32.61)	10.46	(30.60)	11.97	(32.46)
500 or more employees	3.20	(17.61)	3.89	(19.35)	2.71	(16.25)	3.30	(17.88)
East Germany	2.82	(16.55)	16.10	(36.76)	17.71	(38.18)	13.29	(33.95)
Observations	2,342		3,646		3,242		9,230	

Panel B – Worker level	1980-1989		1990-1999		2000-2010		1980-2010	
	mean	sd	mean	sd	mean	sd	mean	sd
D – Manufacturing	73.17	(44.31)	65.74	(47.46)	56.41	(49.59)	64.79	(47.76)
E – Electricity, gas, and water supply	0.34	(5.86)	2.90	(16.78)	0.89	(9.38)	1.55	(12.35)
F – Construction	2.61	(15.94)	1.06	(10.22)	1.20	(10.90)	1.53	(12.28)
G – Wholesale and retail trade	13.06	(33.69)	13.92	(34.61)	18.76	(39.04)	15.24	(35.94)
H – Hotels and restaurants	0.30	(5.44)	0.73	(8.54)	1.04	(10.15)	0.71	(8.41)
I – Transport, storage and communication	3.07	(17.25)	8.63	(28.08)	6.78	(25.14)	6.50	(24.65)
J – Financial intermediation	1.44	(11.93)	1.54	(12.31)	3.09	(17.30)	2.01	(14.04)
K – Real estate, renting and business activities	6.01	(23.77)	5.49	(22.77)	11.83	(32.30)	7.67	(26.61)
50-99 employees	25.08	(43.35)	27.83	(44.82)	31.94	(46.62)	28.39	(45.09)
100-199 employees	24.87	(43.23)	26.63	(44.20)	25.88	(43.80)	25.90	(43.81)
200-499 employees	28.82	(45.29)	25.62	(43.65)	21.24	(40.90)	25.10	(43.36)
500 or more employees	21.23	(40.90)	19.92	(39.94)	20.94	(40.69)	20.61	(40.45)
East Germany	2.40	(15.31)	17.96	(38.39)	14.39	(35.10)	12.52	(33.09)
Observations	86,310		125,942		100,382		312,634	

Notes: The table shows the share of establishments (Panel A) and workers (Panel B) in percentage points as well as the corresponding standard deviations for various establishment-level characteristics. Source: IEB.

Table A3: Occupational routine-intensity

Occupation	1985			1991			1999		
	Rank	Routine-intensity	Obs (weighted)	Rank	Routine-intensity	Obs (weighted)	Rank	Routine-intensity	Obs (weighted)
Mineral preparers	1	49.29	1.40	82	0.00	4.73	83	.	.
Other nutrition occupations	2	43.36	25.62	4	41.83	22.16	8	36.09	29.32
Textile makers	3	40.55	50.68	18	23.63	20.19	2	57.09	17.90
Assistants (no further specification)	4	37.32	694.43	9	33.13	497.01	9	35.49	494.21
Building material makers	5	35.50	17.66	3	42.15	11.53	22	21.24	10.43
Spinners	6	34.02	15.05	1	59.45	16.99	24	18.73	6.25
Metal producers, Rollers	7	32.29	67.83	24	19.33	41.90	12	29.82	40.09
Assemblers and Metal workers (no further specification)	8	32.24	207.63	6	37.21	216.93	10	33.94	150.97
Textile processers	9	30.67	197.26	11	31.20	172.10	14	27.64	93.47
Metal moulders (non-cutting deformation)	10	30.40	92.73	5	39.03	51.73	3	45.67	21.03
Glass makers	11	30.19	26.53	26	16.90	31.83	6	40.83	23.77
Plastics processors	12	29.91	58.48	17	24.87	39.17	17	26.01	41.24
Goods examiner, despatchers	13	29.69	242.99	10	32.61	279.31	11	31.53	278.52
Metal connectors	14	28.91	77.11	8	34.03	121.82	34	13.29	83.60
Chemical workers	15	28.40	201.17	20	21.67	184.28	20	22.06	183.91
Beverage makers, Luxury food makers	16	28.35	29.63	19	23.32	18.35	5	41.34	44.15
Cleaning occupations	17	27.80	257.92	7	34.52	273.69	13	28.21	293.52
Ceramics workers	18	26.62	31.52	2	54.33	29.10	19	22.29	27.43
Machinists and related occupations	19	24.07	306.90	22	19.86	481.72	18	22.80	408.66
Wood preparers, Wood products makers and related occupations	20	23.92	46.90	36	12.10	27.20	27	15.28	35.07
Moulders, Mould casters	21	23.86	38.43	13	30.87	39.33	4	43.99	37.30
Leather makers, Leather and Skin processing operatives	22	19.12	56.58	16	26.05	33.48	38	12.04	23.42
Textile finisher	23	19.12	13.91	14	30.35	8.93	1	63.23	4.19
Watchpersons and related workers	24	19.06	225.71	30	15.33	286.77	40	11.72	297.64
Communication occupations	25	17.95	98.46	12	31.08	98.74	16	26.35	98.22

Occupation	1985			1991			1999		
	Rank	Routine-intensity	Obs (weighted)	Rank	Routine-intensity	Obs (weighted)	Rank	Routine-intensity	Obs (weighted)
Metal moulders (metal-cutting deformation)	26	16.25	153.03	31	15.07	288.27	30	14.68	162.43
Food preparers	27	15.72	179.47	55	6.47	265.72	48	8.98	267.33
Surface transport occupations	28	14.91	817.43	25	19.10	961.02	21	21.44	895.20
Artists	29	14.78	109.03	44	8.25	121.04	67	3.21	93.71
Bakery goods makers, Confectioners (pastry)	30	13.01	121.16	21	21.14	119.90	29	14.86	137.89
Warehouse managers, Stores, transport workers	31	12.94	577.70	39	10.99	483.10	28	15.04	511.33
Road makers, Civil engineering workers	32	12.91	99.35	47	7.40	153.18	41	11.71	188.59
Forestry and Hunting occupations	33	12.44	39.30	49	7.00	70.56	36	12.43	40.44
Precision fitters	34	12.23	76.86	45	7.50	112.36	50	8.95	113.01
Paper makers	35	11.91	52.46	28	15.76	69.65	7	36.97	58.00
Other services agents and related occupations	36	11.02	252.08	54	6.52	219.31	63	4.45	234.33
Building finishers	37	10.17	133.92	46	7.48	130.97	33	13.45	222.90
Painters, lacquerers and related occupations	38	10.11	223.44	37	11.60	324.74	42	11.54	250.67
Carpenters, Roofers, Scaffolders	39	9.41	143.38	56	6.46	201.77	39	12.02	241.87
Butchers, Fish processing operatives	40	9.40	67.33	29	15.54	106.08	15	26.58	87.33
Carpenters, Model maker	41	9.34	210.13	53	6.73	332.16	60	5.57	330.02
Printer	42	8.99	164.44	38	11.00	146.04	31	13.76	156.34
Building labourer, general	43	8.60	194.67	40	10.58	182.38	32	13.64	215.66
Housekeeping occupations	44	8.44	83.18	41	9.98	75.05	49	8.97	97.07
Miners	45	8.29	58.86	48	7.19	60.34	44	10.29	55.98
Mechanics	46	8.16	457.85	52	6.75	681.93	47	9.55	530.95
Metal surface workers, Metal heat-treating-plant operators, Metal couting workers	47	7.95	16.10	23	19.69	30.53	43	11.24	17.22
Room equippers, Upholsterers	48	7.87	55.14	61	5.09	36.97	26	16.42	44.77
Stone preparers	49	7.50	15.99	27	16.47	21.73	46	9.77	15.44
Attending on guests occupations	50	7.50	218.42	32	14.50	166.10	55	6.96	232.57

Occupation	1985			1991			1999		
	Rank	Routine-intensity	Obs (weighted)	Rank	Routine-intensity	Obs (weighted)	Rank	Routine-intensity	Obs (weighted)
Water and Air transport occupations	51	7.01	24.83	77	1.56	37.22	25	18.63	32.86
Accountants, Data processing specialists	52	6.95	510.59	43	8.73	697.89	57	6.16	603.89
Bricklayers, Concrete workers	53	6.67	360.57	42	9.54	560.84	37	12.21	528.50
Other health occupations	54	5.97	515.25	50	6.89	765.27	54	7.10	864.96
Office specialists, Office auxiliary workers	55	5.16	2383.25	63	4.68	2443.76	66	3.96	2268.27
Locksmiths	56	5.11	642.21	64	4.46	948.28	56	6.38	851.75
Electricians	57	4.76	565.48	62	4.75	943.62	58	5.78	804.67
Wholesale and retail trade	58	4.69	1746.37	57	6.43	1621.73	59	5.62	1510.76
Protective services workers	59	4.52	44.21	73	2.81	104.85	51	8.68	69.74
Bank specialists, Insurance representatives	60	4.26	608.65	70	3.50	578.49	68	2.94	596.57
Gardeners	61	4.00	155.70	68	3.83	209.69	65	4.28	324.77
Sheet metal workers	62	3.71	237.90	65	4.37	364.94	45	10.19	543.56
Toolmakers	63	3.63	122.12	76	2.14	139.91	62	5.27	132.39
Technical specialists	64	3.35	251.48	59	5.54	251.21	61	5.48	179.70
Body care occupations	65	3.32	183.76	60	5.14	196.51	52	8.65	179.53
Technicians	66	3.12	592.65	72	2.97	843.24	69	2.88	926.67
Smiths	67	2.84	19.02	33	13.98	15.74	23	19.00	18.92
Teachers	68	1.37	115.86	80	0.13	393.82	71	2.34	259.30
Journalists, Interpreters, Librarians	69	1.26	73.81	67	3.87	92.07	73	2.19	104.84
Management consultants, Organisors, Chartered accountants	70	1.10	413.85	74	2.47	518.66	74	1.68	737.22
Members of Parliament, Senior government officials	71	0.92	81.19	66	4.30	187.77	78	0.00	143.05
Social work associate professionals	72	0.73	239.09	75	2.19	587.91	64	4.33	647.70
Physicians, Pharmacists	73	0.72	59.67	69	3.82	101.93	76	0.34	110.57
Engineers	74	0.53	308.71	79	0.49	725.74	75	1.13	634.89
Mineral, Oil, Natural gas quarries	75	0.00	16.19	83	0.00	5.12	79	0.00	4.15

Occupation	1985 Rank	1985 Routine-intensity	1985 Obs (weighted)	1991 Rank	1991 Routine-intensity	1991 Obs (weighted)	1999 Rank	1999 Routine-intensity	1999 Obs (weighted)
Legal and related business associate professionals	76	0.00	10.90	58	6.29	24.00	53	8.61	22.87
Ministers of religion	77	0.00	14.59	81	0.00	10.85	77	0.00	30.18
Farmers	78	0.00	18.70	34	13.72	30.32	70	2.62	32.56
Managers, Advisors in agriculture and animal breeding	79	0.00	16.00	51	6.79	29.29	81	0.00	13.69
Chemists, Physicists, Mathematicians	80	0.00	47.98	71	3.11	71.61	80	0.00	74.32
Humanities specialists, Scientists	81	0.00	85.34	78	1.18	130.44	72	2.23	150.88
Animal breeders; Fishermen	82	0.00	3.57	15	29.39	29.57	82	0.00	6.01
Land workers, Animal keeper	83	0.00	23.05	35	12.68	111.76	35	13.25	57.44

Notes: The table shows the average routine-intensity for each occupation and survey year. Routine-intensity is defined as the weighted share of workers reporting the following two items are the case almost always: i) Are the contents of your job minutely described by your employer, ii) Does the job sequence repeat itself regularly. 'Rank' refers to the ordering of occupations according to routine-intensity (from highest to lowest). 'Obs' shows the weighted number of observations from which the routine-intensity variable is derived. Weights refer to the sampling weights provided as part of the employee survey. Sources: IEB, BIBB-IAB employee survey.

Table A4: Effects of routine-intensity on earnings (robustness)

	(1)	(2)	(3)	(4)
Dependent variable: Quarterly earnings relative to average earnings before the mass layoff				
	Relative change (k = 1)	Relative change (average)	Average absolute value (before ML)	Absolute change (cumulative)
Baseline specification	-0.62 (0.10)***	-0.38	10,052.46	-925.23
Panel A – Alternative model specification				
Control variables instead of individual fixed effects	-0.54 (0.08)***	-0.18	10,052.46	-446.17
Panel B – Alternative routine-intensity measures				
Often or always almost	-0.45 (0.09)***	-0.29	10,052.46	-695.77
Survey 1985	-0.72 (0.09)***	-0.43	10,052.46	-1,041.44
Survey 1991	-0.57 (0.09)***	-0.34	10,052.46	-830.75
Survey 1999	-0.57 (0.12)***	-0.35	10,052.46	-857.30

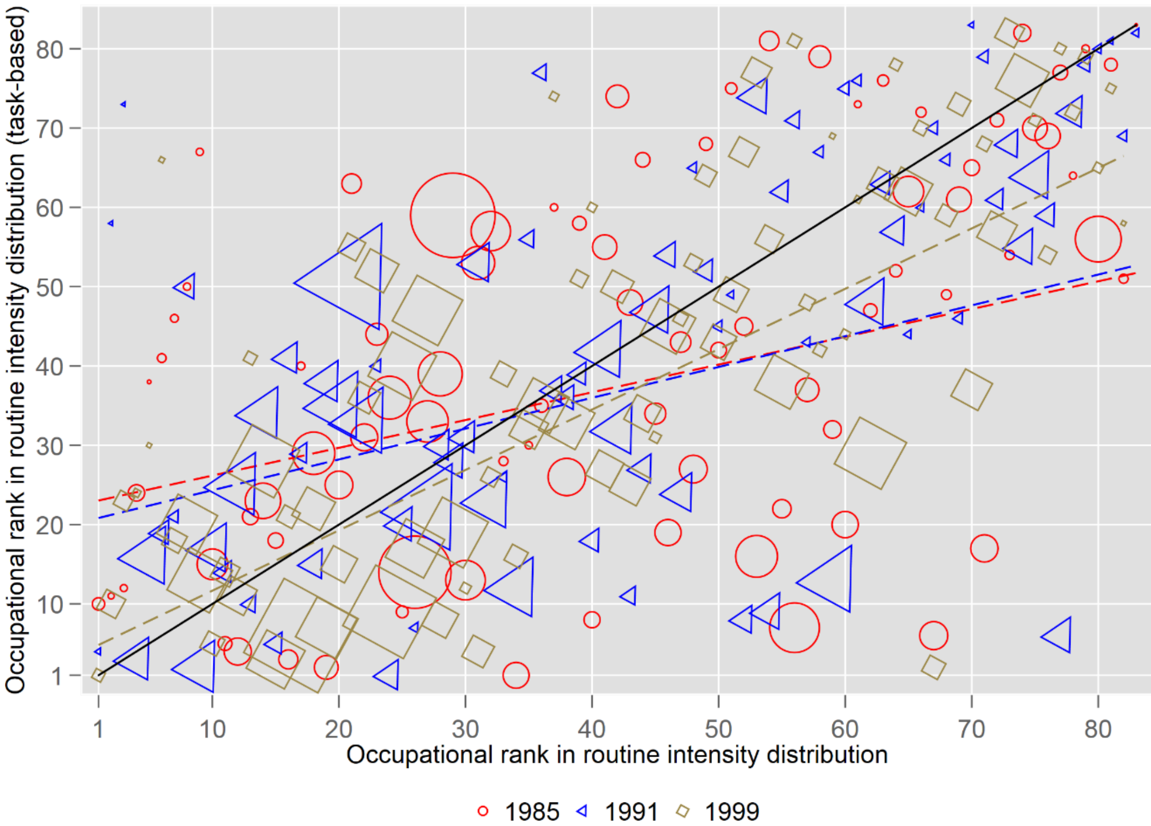
<u>Notes:</u> See Table 6. Sources: IEB, BIBB-IAB employee survey.

Table A5: Comparing outcomes immediately before and after the mass layoff

Outcome	(1) Quarter before mass layoff (k = -1)	(2) Quarter after mass layoff (k = 1)	(3) % change
Panel B – Workers in low-routine occupations			
Earnings (quarterly)	13,528.89	10,627.35	-21.45
Days in employment (quarterly)	91.49	71.19	-22.19
Average daily wage	147.87	121.07	-18.12
Panel C – Workers in high-routine occupations			
Earnings (quarterly)	7,314.06	3,961.67	-45.83
Days in employment (quarterly)	91.52	48.93	-46.54
Average daily wage	79.92	48.63	-39.15

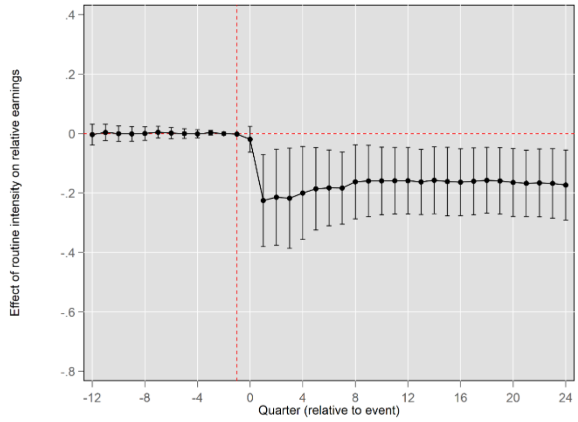
Notes: The table shows the average values of the outcome variables for the quarters directly preceding and following the mass layoff as well as the percentage change in these values. Low-routine occupations refer to the first quarter of the routine-intensity distribution during the quarter before the mass layoff, while high-routine occupations refer to the fourth quarter. Sources: IEB, BIBB-IAB employee survey.

Figure A1: Comparison of routine-intensity measures



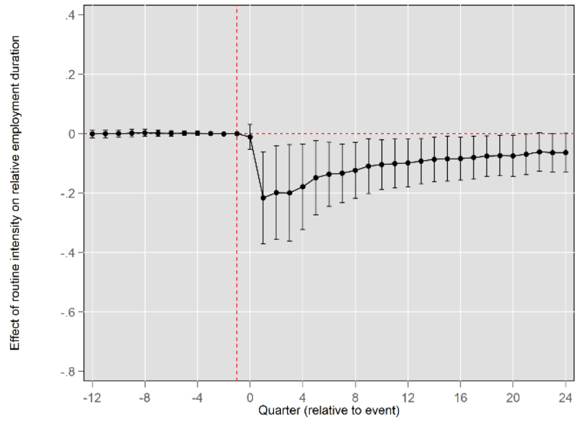
<u>Notes:</u> The figure compares the position of 83 occupations in the distribution of the routine-intensity measure and a task-based measure for each of the survey years 1985, 1991 and 1999. The size of the markers is proportional to the weighted sum of observations in each occupation. The solid black line illustrates the hypothetical case in which the ranking of the occupation was identical for both measures. The dashed lines represent linear fits for each survey year derived from a weighted regression of the rank from the task-based measure on the rank of the routine-intensity measure introduced in Section 2.2. Sources: IEB, BIBB-IAB employee survey.

Figure A2: Effect of routine-intensity on relative earnings (task-based routine-intensity measure)



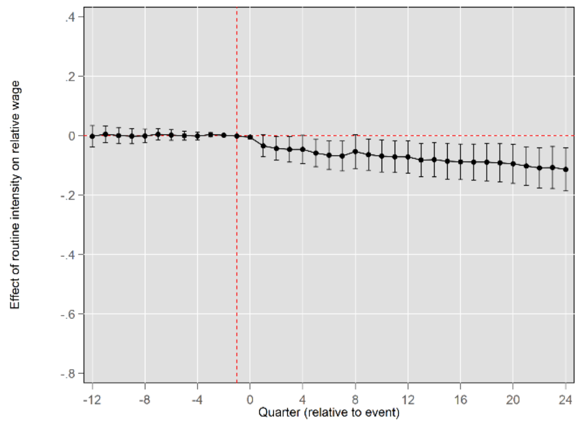
<u>Notes:</u> See Figure 4. A task-based measure of routine-intensity is used. Sources: IEB, BIBB-IAB employee survey.

Figure A3: Effect of routine-intensity on relative employment duration (task-based routine-intensity measure)



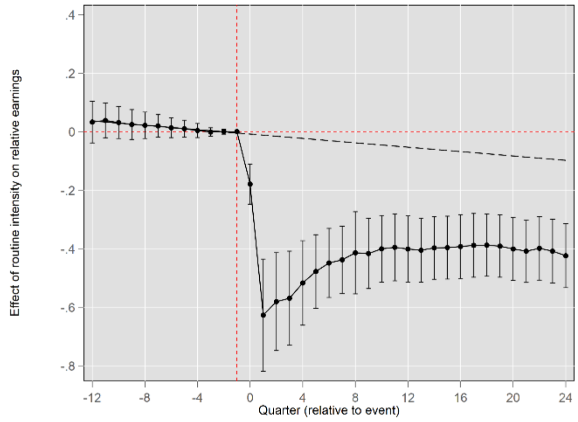
<u>Notes:</u> See Figure 5. *A task-based measure of routine-intensity is used. Sources: IEB, BIBB-IAB employee survey.*

Figure A4: Effect of routine-intensity on relative average daily wages (task-based routine-intensity measure)



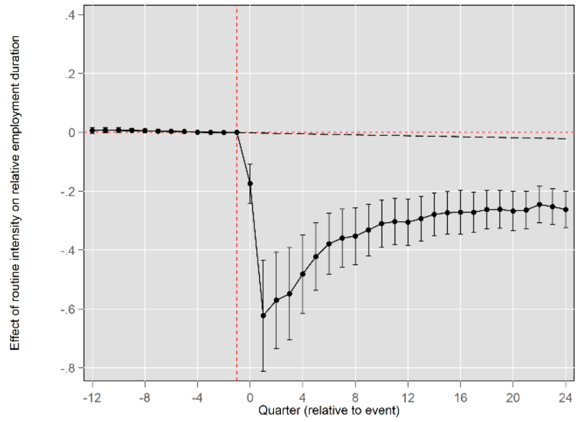
<u>Notes:</u> See Figure 5. *A task-based measure of routine-intensity is used. Sources: IEB, BIBB-IAB employee survey.*

Figure A5: Effect of routine-intensity on relative earnings (without adjustment)



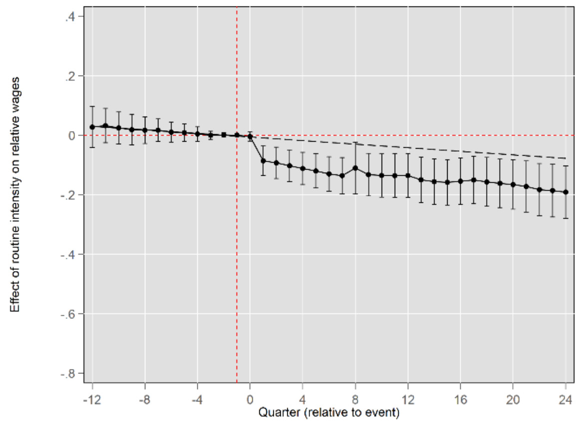
Notes: See Figure 4. The effects displayed in Figure 4 correspond to the vertical distance between the coefficient estimate and the black dashed line. Sources: IEB, BIBB-IAB employee survey.

Figure A6: Effect of routine-intensity on relative employment duration (without adjustment)



Notes: See Figure 5. The effects displayed in Figure 5 correspond to the vertical distance between the coefficient estimate and the black dashed line. Sources: IEB, BIBB-IAB employee survey.

Figure A7: Effect of routine-intensity on relative average wage (without adjustment)



Notes: See Figure 5. The effects displayed in Figure 5 correspond to the vertical distance between the coefficient estimate and the black dashed line. Sources: IEB, BIBB-IAB employee survey.