The Labor Market Effects of Flood Events

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Abstract

We study how floods affect workers' careers, using administrative data for Germany with geocoded home and workplace addresses and three large flood events (2002, 2013 and 2021). A matched difference-in-differences design compares workers in affected municipalities with similar workers in unaffected municipalities, and separates workers whose home or workplace was flooded from workers who were only indirectly affected. After the 2021 flood, directly affected workers lose 2.2% of annual earnings and are 1.7 percentage points less likely to be employed; indirectly affected workers lose much less. Losses are concentrated among workers whose home was flooded and rise with building damage; layoffs hit workers whose workplace was flooded. Defining exposure at the municipality level misses three quarters of the earnings loss of directly affected workers. The earlier floods had smaller or even positive effects; differences in the composition of the affected workforce explain most of this gap.

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1 Introduction

Natural disasters are becoming more frequent, they affect more people, and the losses they cause are rising. In Europe, the number of recorded floods has roughly doubled since the 1950s, the number of people affected by them has more than doubled, and the inflation-adjusted flood losses of 2020–2024 alone already exceed those of any earlier decade (Paprotny, 2025).[1] When a natural disaster hits a developed country, governments often act as insurer of last resort and fund the rebuilding of homes, firms and infrastructure. Whether this shields workers from lasting labor market losses is an open question: estimates range from sizable short-run earnings losses after Hurricane Katrina (Deryugina et al., 2018; Groen et al., 2020) to gains in other settings (Kirchberger, 2017; Nakamura et al., 2022).

We argue that two features explain much of this disagreement. First, most studies define exposure at the level of regions, pooling the few workers whose home or workplace was hit with the many who only live in the same region. Second, disasters differ in their context: in the workers they hit and in the aid that follows. Understanding these dynamics is essential for designing effective disaster responses as climate risk continues to expand.

In this paper, we exploit large-scale geo-coded administrative data for Germany, spanning 1997–2024 and linked to geo-coded information on flood exposure, to shed light on who loses from a flood and why. We focus on the largest flood event in Germany in the past three decades: the 2021 flood that affected several regions in Western Germany, and the Ahr valley in particular.[2] Using a matched difference-in-differences design (DiD) in combination with a spatial regression-discontinuity-design (RDD), we document three facts: First, workers whose home was flooded exhibit the largest earnings losses, driven by a loss of employment. Second, the channels of job loss differ by type of exposure: workers whose home was flooded lose their jobs mainly through labor supply, such as sick leave and retirement, whereas mass layoffs concentrate among workers whose workplace was flooded. Third, a region's workforce composition, in particular its age, is a key factor contributing to negative labor market effects.

One key empirical challenge when studying the causal labor market effects of natural disasters is that regions, and workers, are not randomly exposed. Our baseline empirical design tackles this challenge: We employ a two-step matching approach that first matches regions, and then within matched-region-pairs matches treated to control workers. This leaves treated and control workers who are close in demographics and wage histories, with small differences in tenure and establishment size. We complement the baseline design with a spatial RDD that exploits distance to the flooded area as the main discontinuity. Similar to the literature on mass layoffs (Jacobson et al., 1993; Schmieder et al., 2023), we focus on workers with stable employment trajectories before the flood event.[3]

Our setting is a developed country context where governments typically react to big natural disasters by paying out significant emergency and reconstruction aid. Germany experienced three large flood events in the past three decades, ranging from EUR 6.7 billion (2013 Elbe/Donau flood) to EUR 33 billion in damages; only a fraction of these losses was insured (see Appendix Table A1). After each flood, the government set up emergency aid programs as well as longer-term

[1] Much of this rise reflects growing exposure, as more people and assets are located in flood-prone areas (Paprotny et al., 2018). Appendix Figure A1 shows the trends for Europe and the yearly flood losses in Germany.

[2] Appendix Figure A1 shows that the 2021 flood caused by far the largest financial losses of all floods in Germany since 1990, about EUR 36 billion in 2024 prices. An advantage of our data is that we can compare the 2021 flood to two other large flood events in Germany; the 2002 flood that affected mainly the rivers Elbe and Mulde, and the 2013 flood that affected mainly the rivers Elbe and Donau.

[3] At baseline, 84% of the workers in the treatment regions of the 2021 flood were in employment.

reconstruction funds to support rebuilding efforts. Ex-ante, it is therefore unclear how these flood events affected labor market characteristics: damage and destruction may have led to losses, while a stimulus from rebuilding efforts may have led to gains.

To organize the analysis, we develop a simple conceptual framework. A flood affects workers through two opposing forces. On the one hand, it disrupts: damaged homes reduce labor supply, for example through sickness, time spent on repairs, or temporary displacement; damaged workplaces reduce labor demand through establishment closures and layoffs. On the other hand, emergency aid, insurance payouts and reconstruction funds stimulate local labor demand, in particular in construction and related sectors. A worker's net effect is the stimulus minus the disruptions. Both depend on how the worker is exposed—through the residence, the workplace, or only through the local labor market—as well as on the severity of the damage, the time since the flood, and the context of the flood, such as the volume and the speed of aid.

The framework predicts that directly affected workers fare worse than indirectly affected workers, that losses rise with the damage, and that the channels differ by type of exposure: home exposure lowers labor supply, whereas workplace exposure lowers labor demand through establishment closures and layoffs. Finally, the model shows that a treatment definition at the municipality level, which pools directly and indirectly affected workers, understates the losses of the directly affected.

Empirically, we document moderate overall earnings and employment losses for individuals affected by the 2021 flood, with important heterogeneity: In the three years after the flood event, directly affected workers are 1.7 percentage points less likely to be employed relative to their matched control (0.6 percentage points for indirectly affected workers). This translates into earnings losses of around EUR 817 per year, about 2.2% of the baseline earnings of their matched controls. Indirectly affected workers, in contrast, do not lose earnings: their loss of EUR 150 per year is small and not statistically significant.

The results confirm most predictions of the framework. First, exposure matters: the losses are concentrated among workers whose home was flooded, who are 3.4 percentage points less likely to be employed and lose EUR 1,770 in earnings per year.[4] Second, losses rise with damage: workers whose home or workplace was graded as damaged lose about 2.4 percentage points of employment, three times as much as workers in assessed areas without recorded damage. Third, the channels differ by type of exposure: workers whose home was flooded leave employment mainly through sick leave and retirement, whereas layoffs hit workers whose workplace was flooded. Contrary to the framework, however, workers whose workplace only was flooded show no net loss, which suggests that displaced workers whose home stayed dry quickly found new jobs. Finally, there are signs of the rebuilding stimulus: directly affected workers are more likely to move to higher-paying establishments and into construction. Losses are largest for workers aged 50 or older (5.7 percentage points and EUR 3,233 per year), for whom retirement plays an important role.

While the 2021 flood negatively affected workers' labor market outcomes, the pattern is less clear for the floods in 2013 and 2002. The 2013 flood had mostly zero average effects for affected workers, while the 2002 flood even led to small employment gains for indirectly affected workers. In line with the framework, which traces differences between floods to the exposure mix, worker composition and context, we show that baseline workforce and regional characteristics account for most of these differences. Once we reweight workers affected in 2021 to workers affected in 2002 or 2013, based on individual and regional characteristics, the employment losses largely disappear.[5] Affected workers' age is the most important explanatory variable, followed by county unemployment

[4] A spatial regression discontinuity design at the border of the flooded area, which compares workers within the same municipalities and does not rely on matching, confirms these results: employment drops by 1.9 to 2.7 percentage points for workers who live just inside the flooded area, and there is no drop at the border for workplaces.

[5] This result is robust to using a double-selection lasso following Belloni et al. (2014) instead.

rate.

The results are robust to dropping municipalities within the top decile of ex-ante flood risk, dropping bigger cities with more than 230,000 employees, and varying standard errors and fixed effects.

We contribute to the growing literature on the impact of natural disasters on workers' labor market outcomes (Deryugina et al., 2018; Groen et al., 2020; Nakamura et al., 2022; Borgschulte et al., 2024; Schwank, 2024). Our high-quality geo-coded data that is available over a long time frame allows us to study several flood events that happened in the same country. We show that the labor market effects of flood events are highly context-dependent. Even within the same country, flood events may have very different labor market effects, depending on a region's workforce composition and ex-ante unemployment rate. Our precise geo-coded data also allow us to decompose total labor market effects by exposure type. Groen et al. (2020) show that damage to workers' homes and workplaces, assigned at the level of Census blocks, accentuated the short-run earnings losses after Hurricanes Katrina and Rita. We observe the residence and the workplace of every worker at the address level and combine them with building-level damage grades. This allows us to separate workers whose home only, workplace only, or both were flooded from workers in the same municipalities whose home and workplace stayed dry. We show that workers whose home was flooded experience the largest losses, and that pooling indirectly and directly affected workers on the municipality level would, as the framework predicts, severely underestimate their losses.

Several studies have analyzed the impact of natural disasters on regions, firms, and workers. A first group of studies documents long-run consequences for regions and cities: population, economic activity, and land use (Hornbeck and Naidu, 2014; Siodla, 2015, 2017; Ager et al., 2020; Boustan et al., 2020). For floods in the United States, Jia et al. (2026) find that flood events lower output in the short run but have limited effects on firm entry and employment, whereas rising flood risk lowers firm entry, employment, and output in the long run. A second group studies firms, from the location and agglomeration of businesses (Siodla, 2021) to the performance of firms hit by the 2013 flood in Germany (Noth and Rehbein, 2019). A third group studies mobility and migration responses (Boustan et al., 2012; Hornbeck and Naidu, 2014; Long and Siu, 2018; Hornbeck, 2023; Patel, 2024; Spitzer et al., 2025), and a fourth the consequences for schooling and human capital (Sacerdote, 2012; Caruso and Miller, 2015; Patel, 2024). A fifth group studies attitudes, trust, and political behavior (Andrabi and Das, 2017; Holub and Schündeln, 2023; Hoenow et al., 2025). Related studies analyze local labor markets in a developing-country context (Kirchberger, 2017) and the fiscal costs of disasters through disaster aid and social insurance (Deryugina, 2017). We contribute to this literature by studying the labor market effects for workers with previously stable employment biographies, in the context of flood events in Germany.

Our paper is also related to the literature on job displacement, which documents large and persistent earnings losses for workers who lose their job in a mass layoff or plant closure (Jacobson et al., 1993; Couch and Placzek, 2010; Davis and von Wachter, 2011; Lachowska et al., 2020; Fackler et al., 2021; Schmieder et al., 2023). Our empirical strategy borrows from this literature: as in studies of displaced workers, we focus on workers with stable employment careers before the event and compare them with matched control workers who were not affected. This makes our estimates directly comparable. We show that job loss is not the only shock that can derail stable careers: natural disasters hit workers as well, although far less severely. Our estimates of earnings losses are an order of magnitude smaller than those in the job loss literature. At the same time, the two shocks are linked: a large part of the employment losses after the flood runs through mass layoffs, and workers in the same local labor market who are not directly hit lose about as much as non-displaced workers in regions hit by a mass layoff (Gathmann et al., 2020).

The remainder of the paper is structured as follows. Section 2 presents the conceptual framework.

Section 3 describes the three floods and the insurance and public aid that followed them. Section 4 introduces the data, and Section 5 explains the empirical strategy. Section 6 presents the results: the effects of the 2021 flood by type of exposure and severity of the damage, the channels behind the employment losses, mobility, the workers who are affected most, and the comparison with the floods of 2013 and 2002. Section 7 concludes.

2 Conceptual framework

A flood does two things at once. It *disrupts*: homes and workplaces are damaged, people fall ill or are absorbed by repairs, and establishments close or lay off workers. And it *stimulates*: aid, insurance payouts and rebuilding raise local labor demand. This section sets out a simple accounting framework that separates these forces by how a worker is exposed to the flood. The framework is reduced-form and serves to organize our empirical comparisons and the mechanisms we examine.

Setup Worker i is employed at baseline in a municipality hit by flood f. Let $h_i = 1$ if the worker's home lies inside the flooded area and $w_i = 1$ if the workplace does. This defines four exposure types: indirectly affected workers ($h_i = w_i = 0$), and directly affected workers whose workplace only (W), home only (H), or both (B) were flooded. $\tau_i(k)$ denotes the effect of the flood on an outcome such as earnings or employment in year $k \geq 1$ after the flood, relative to a matched control worker in an unaffected municipality.

Net effect We write the effect as the net local labor market effect minus two disruptions:

$$\tau_i(k) = \underbrace{\widetilde{R}_f(k)}_{\text{net local effect}} - h_i \underbrace{S_f(k)}_{\text{labor-supply disruption}} - w_i \underbrace{L_f(k)}_{\text{labor-demand disruption}}. \tag{1}$$

Home exposure lowers labor supply (S_f): sickness, time spent on repairs and temporary displacement keep workers from work in the short run, and some older workers retire early. *Workplace exposure* lowers labor demand (L_f): flooded establishments close or lay off workers. How much displaced workers lose depends on how quickly they find a new job, which in turn depends on the state of the local labor market.

In addition to these direct disruptions, the flood generates local general-equilibrium effects that also reach workers whose own homes and workplaces remain unaffected. These include positive effects from reconstruction activity, supported by aid and insurance payments, and other positive spillovers (R_f), as well as negative effects from disruptions to local economic activity, supply chains and infrastructure (N_f). We denote the net local labor market effect by $\widetilde{R}_f(k) = R_f(k) - N_f(k)$. Its sign is ambiguous and depends on the relative strength of these forces. All else equal, reconstruction spending increases the positive component, with gains likely to be strongest in construction and related sectors. All components depend on the severity of the damage, on the time since the flood, and on the context of the flood, in particular the volume and speed of aid.

Effects by exposure type Averaging (1) within exposure types gives

$$\tau_0 = \overline{\widetilde{R}}, \qquad \tau_W = \overline{\widetilde{R}} - \bar{L}, \qquad \tau_H = \overline{\widetilde{R}} - \bar{S}, \qquad \tau_B = \overline{\widetilde{R}} - \bar{S} - \bar{L}, \tag{2}$$

where bars denote averages and we suppress the time index. The effect for indirectly affected workers captures the net local labor market effect, reflecting both reconstruction activity and negative local

spillovers. Assuming this effect is common across exposure types, comparisons with indirectly affected workers capture the additional losses associated with home exposure ($\bar{S}$) and workplace exposure ($\bar{L}$).

Municipality-level estimates Most studies treat all workers in an affected region as exposed. With s_m the share of directly affected workers in municipality m and τ_D their average effect, such an estimate equals

$$\tau_m^M \;=\; (1 - s_m)\,\tau_0 + s_m\,\tau_D. \tag{3}$$

Because few workers in an affected municipality are directly affected, τ_m^M is close to the indirect effect and understates the losses of directly affected workers.

Implications The framework has four main implications that guide the empirical analysis. First, exposure matters: directly affected workers fare worse than indirectly affected workers, both when their home is flooded ($\tau_H < \tau_0$) and when their workplace is flooded ($\tau_W < \tau_0$). Second, among directly affected workers, losses rise with the damage to the home or the workplace. Third, the channels differ by type of exposure: home exposure lowers employment through labor supply, visible in sick leave and retirement, whereas workplace exposure lowers employment through labor demand, visible in establishment closures and mass layoffs. Fourth, a treatment definition at the municipality level understates the losses of directly affected workers, the more so the smaller their share.

3 Background: three large flood events in Germany

This section describes the three floods we study and the insurance and public aid that followed them. The floods differ in the dimensions that the framework of Section 2 highlights: the severity and type of the damage, and the volume and speed of the payments that finance reconstruction. Appendix Table A1 compares the floods and lists the sources; Appendix A gives more details on insurance and public aid.

The three floods We study the floods of August 2002, June 2013 and July 2021. They are by far the costliest floods in Germany since 1990: their losses amount to about EUR 15.6, 11.0 and 35.8 billion in 2024 prices, while flood losses exceed EUR 3.2 billion in no other year (Appendix Figure A1; Paprotny, 2025). For all three, the extent of the flooded area has been mapped, and each affected enough workers to estimate effects by type of exposure. The floods of 2002 and 2013 were river floods along the Elbe, the Mulde and the Danube that built up over several days. The flood of 2021 followed extreme rainfall over small catchments in Rhineland-Palatinate and North Rhine-Westphalia, above all along the Ahr and the Erft. The water rose within hours, left little time for warnings, and at least 189 people died (DKKV, 2022). The official damage estimate for 2021, about EUR 33 billion, is three times that of 2002 (11.6 billion) and five times that of 2013 (6.7 billion) (BMI, 2013, 2022). The 2021 flood also hit private homes harder: in Rhineland-Palatinate, private households bore 50–55% of the damage, compared with 22–24% in 2002 and 2013 (Pfurtscheller and Thieken, 2013; BMI, 2022). At the same time, the damage was concentrated on a small area. On average, 2% of the area of an affected municipality was flooded in 2021, compared with 6% in 2002 and 9% in 2013 (Appendix Table A1).

Insurance Insurance against floods is voluntary in Germany, and insured losses covered only a small part of the damage: EUR 1.9 billion in 2002, 1.8 billion in 2013 and 8.6 billion in 2021 (GDV,

2025). In 2002, about 4% of residential buildings in Germany were insured against floods; by 2021, this share had risen to about 46% (DKKV, 2003, 2022). Coverage in the regions hit in 2002 was higher than the national figure suggests, because about 3 million households in eastern Germany still held insurance contracts from the former GDR that covered floods. In a survey of flood-damaged households in Saxony and Saxony-Anhalt, half were insured (DKKV, 2003).

Public aid After each flood, the federal government and the states provided aid in two stages. *Emergency aid* was paid within days or weeks to households, firms, farmers and municipalities and covered immediate needs. *Reconstruction funds*, set up by law within weeks of each flood, financed the rebuilding of homes, businesses and infrastructure. The rules were similar across floods: after the damage had been assessed, the funds covered up to 80% of the damage that remained after insurance payments and emergency aid. In 2021, they covered up to 100% in cases of hardship, and holding flood insurance was not a condition for aid. What differed was the size of the aid relative to the damage, and its speed. Emergency aid amounted to 13–14% of the damage in 2002 and 2013, but to about 2% in 2021 (BMI, 2002; BT-Drs. 17/14743; BT-Drs. 19/32497). The reconstruction funds were large in all three cases (EUR 7.1, 8 and 30 billion), but they paid out slowly after 2021: about three years after the flood, the fund had paid out a third of the damage of the 2013 flood, but only about a tenth of the damage of the 2021 flood (BT-Drs. 18/9354; BT-Drs. 20/14000).

Measures in the labor market Several measures affected labor market outcomes directly. Establishments could use short-time work. In 2002 and 2013, the social security contributions for short-time work were reimbursed (BMI, 2002; BT-Drs. 17/14743). In 2021, the special rules introduced during the COVID-19 pandemic still applied: short-time work required only 10% of the workforce to be affected, and the social security contributions were reimbursed in full until September and by half from October to December 2021 (BDA, 2021). Establishments that were flooded themselves could claim short-time work at once, as for an unavoidable event; establishments affected only indirectly, for example through a flooded supplier, could claim it only on economic grounds. Short-time work was not available for workers whose home was flooded if their establishment was not affected; these workers had to take leave or be released from work (BDA, 2021). Workers on short-time work remain employed in our data, while their earnings fall. After each flood, the duty to file for insolvency was temporarily suspended for firms hit by the flood, which delays establishment closures (BT-Drs. 14/9934; BT-Drs. 17/14078; BMI, 2022). In 2002, public funds financed up to 5,000 temporary jobs in clean-up work (BMI, 2002). In 2013 and 2021, job centers in the affected regions received additional funds, and in 2021 visas for reconstruction workers were processed faster (BT-Drs. 17/14743; BMI, 2022).

Implications for the comparison of floods In terms of the framework, the 2021 flood combines a stronger disruption with a weaker stimulus in our observation window. The damage per affected place was more severe and came with less warning, and a larger share of it fell on private homes, the type of exposure that lowers labor supply. Aid was small relative to the damage in the first months and reached households and firms more slowly than after the earlier floods. We therefore expect larger losses for directly affected workers, and smaller gains for indirectly affected workers, after 2021 than after 2002 and 2013. Differences between the floods can also reflect who was affected: the floods hit regions with different workforces, a point we return to when we compare the three floods.

4 Data

4.1 Flood extent and building damage

We combine three types of spatial information on the floods of August 2002, June 2013 and July 2021. First, flood-extent maps show which areas were inundated. They come from state environmental agencies, federal agencies and, for 2021, the Copernicus Emergency Management Service. For 2002 and 2013, nationwide maps are not available; we use maps for the most severely affected federal states, which cover the large majority of the damage. Appendix B lists the sources and the processing steps. From these maps, we define *affected municipalities* as municipalities with a non-zero flooded area. Figure 1 shows the affected municipalities and, for one municipality per flood, the flooded area inside it.

Second, for the 2021 flood we use the building-damage grading of the Copernicus Emergency Management Service for the most affected areas. It classifies buildings inside the assessed areas as possibly damaged, damaged or destroyed (Appendix Figure A16). A residence or workplace receives the grade of the nearest graded building within 10 meters. Places inside an assessed area without a graded building within 10 meters are classified as "no damage recorded"; places outside the assessed areas have an unknown damage status and are not used in the damage analysis.

Third, we measure the ex-ante flood risk of each municipality with the flood hazard maps that the federal states drew up under the EU Floods Directive (Directive 2007/60/EC) and that the Federal Institute of Hydrology (*Bundesanstalt für Gewässerkunde*) compiled for Germany in 2013. The maps delineate the areas that would be inundated by floods with a high, a medium and a low probability. For every municipality, we compute the share of its area that lies in the high-probability zone. The maps were compiled in 2013 and therefore predate the 2021 flood. They do not yet reflect the flood of June 2013 either.[6] For the 2002 flood, the measure may partly reflect where the flood occurred.

4.2 Administrative worker data with geocoded addresses

Our main data are the Integrated Employment Biographies (IEB) of the Institute for Employment Research (IAB). The IEB cover all employment subject to social security contributions, marginal employment, registered unemployment and benefit receipt, with exact start and end dates. They exclude civil servants and the self-employed. The data contain daily wages, the establishment, industry, occupation, and the worker's age, gender and education. We draw all workers who lived or worked in an affected municipality or in a matched control municipality (Section 5.2) on the day before each flood: 5 August 2002, 1 June 2013 and 13 July 2021. We refer to this day as the *reference date*.

A key feature of our data is that residence and workplace addresses are geocoded. We use the coordinates of the residence and of the establishment on the reference date to determine whether a worker's home and workplace lay inside the flooded area, how far they were from its border, and, for 2021, their damage grade. When a worker has several address records on the reference date, we keep records whose geocode is unambiguous and, for 2021, lies in the municipality recorded in the IEB, prefer records from the data on means-tested benefits over those from the employment data and other sources, drop workers whose records differ by more than 5 meters in their distance to the flooded area, and otherwise keep the record with the smallest distance or the one that starts later. Appendix B describes these steps.

[6] Information from the Federal Institute of Hydrology (BfG), which compiled the maps.

We transform the spell data into a yearly panel (Dauth and Eppelsheimer, 2020). Status variables refer to the reference date in each calendar year, for example 13 July in every year for the 2021 flood; if a worker holds several jobs on that date, we keep the one with the highest daily wage. Annual earnings and days worked are summed over all employment spells in the calendar year. Daily wages above the social security contribution ceiling are imputed, and all wages and earnings are deflated to 2015 prices with the consumer price index. Education is corrected following Fitzenberger et al. (2008). Workers who do not appear in the data in a given year are kept in the panel as not employed, with zero earnings and days worked and a missing wage. The panel covers 1997–2007 for the 2002 flood, 2009–2018 for the 2013 flood and 2017–2024 for the 2021 flood.

Outcomes Our main outcomes are annual earnings (including all employment), employment on the reference date, the log daily wage of the main job, and days worked per year. We further use days worked and earnings in full-time jobs, days receiving unemployment benefits, marginal employment, and mobility indicators that equal one if the establishment, the workplace or residence municipality or county, the occupation or the industry differs from that on the reference date. To study reallocation across establishments, we use whether a worker is still at the baseline establishment, has entered construction or the public sector (public administration, education, health), and the establishment fixed effect of the current employer from AKM wage regressions estimated on the IEB for 1993–2000, 2001–2008, 2009–2016 and 2017–2023 (Lochner and Wolter, 2025).

Channels of non-employment For the 2021 flood, we assign every worker who is not employed in a given year to one of seven mutually exclusive channels. *Establishment closure* and *mass layoff* are defined from worker flows in the Establishment History Panel (BHP), following Hethey-Maier and Schmieder (2013): the worker leaves an establishment whose employment falls by at least 90% (closure) or at least 30% (mass layoff) within a year, and is not employed in the following year. *Sick leave* is identified from the reason codes with which employment spells end. *Retirement* applies to workers aged 62 or older in 2021 who no longer appear in the data in 2022–2024. The remaining non-employed workers have either *left the data* (self-employment, civil service, moving abroad, death, early retirement before age 62 or disability pensions) or are still in the data, with or without *unemployment benefits*. Workers who meet the conditions of several channels are assigned in the order closure, mass layoff, sick leave, retirement. Appendix D gives the exact definitions.

Other data From the BHP, we take establishment characteristics. Inspired by Caldwell and Danieli (2024) and following Illing et al. (2026), we construct a measure of workers' outside options: the employment in each two-digit occupation in the worker's commuting zone, weighted by the share of job changes from the worker's own occupation into that occupation. Municipality and county characteristics come from INKAR (settlement type, population, migration), the Federal Statistical Office (county unemployment rates), the Statistical Offices of the Federation and the States (county GDP), and the Federal Agency for Cartography and Geodesy (river length relative to municipal area). Information on damages, insurance and public aid comes from laws, parliamentary documents and official reports (Appendix Table A1).

5 Empirical strategy

5.1 Treatment and exposure

We distinguish two groups of treated workers. *Directly affected* workers lived or worked inside the flooded area on the reference date. *Indirectly affected* workers lived or worked in an affected

municipality, but outside the flooded area. Among directly affected workers, we further distinguish whether the workplace only, the home only, or both were flooded, and, for 2021, the damage grade of the flooded place. Formally, let $D_i = 1$ if worker i lived or worked in an affected municipality on the reference date, and let h_i and w_i indicate a flooded home and a flooded workplace, as in Section 2. The treated workers fall into four mutually exclusive exposure groups,

$$D_i = \underbrace{D_i(1-h_i)(1-w_i)}_{G_i^I\text{: indirect}} + \underbrace{w_i(1-h_i)}_{G_i^W\text{: workplace only}} + \underbrace{h_i(1-w_i)}_{G_i^H\text{: home only}} + \underbrace{h_i\,w_i}_{G_i^B\text{: both}}, \tag{4}$$

and the characteristics of the treated worker define the group of the matched pair. Because treatment can arise through the residence or the workplace, we build four matched samples per flood: workers whose workplace (residence) was flooded, and workers whose workplace (residence) lay in an affected municipality but was not flooded. A worker whose home and workplace were both flooded enters both samples of directly affected workers. To avoid treatment definitions driven by very few workers, we exclude affected municipalities with fewer than ten flooded workers, separately for residence and workplace.[7] Table 1 describes the treated workers of 2021 by exposure type, and Appendix Table A8 reports the number of workers by flood and exposure type.

5.2 Matching

We match in two steps: first municipalities, then workers within pairs of municipalities.

Control municipalities For each flood, we match every affected municipality to one municipality that was not flooded, using characteristics of the municipality and of its county in the year before the flood. Potential controls exclude all municipalities flooded in any of the three floods and all municipalities in a county with an affected municipality, because their workers may be exposed to the same local shocks through supply chains, commuting or reconstruction demand. They further exclude municipalities in the river basins downstream of the affected areas and, for 2021, municipalities in counties that Hoenow et al. (2025) classify as exposed to the flood. We match exactly on East or West Germany, the size class of the municipality, an indicator for a median wage above the regional median, and an indicator for a local economic downturn. Within these cells, we choose the nearest neighbor without replacement by the Mahalanobis distance over the municipality's population, employment, age structure and river length, and over the industry structure, population density, median wage, unemployment rate, migration rates and settlement type of its county. Appendix C gives the details, and Appendix Tables A27 and A28 compare affected and matched control municipalities in the year before each flood.

Workers Within each pair of municipalities, we match each treated worker to one control worker from the control municipality (nearest neighbor without replacement). Similar to the literature on job displacement, we restrict both groups to workers who were employed on the reference date and in the two preceding years, had at least three years of tenure with their employer and in their occupation, and had not moved residence in the past three years. Matching is exact on gender, the municipality pair, the skill level of the occupation, and the deciles of the log daily wage in each of the three years before the flood. Within these cells, we minimize the Mahalanobis distance over tenure with the employer and in the occupation, age, industry, occupational field, days worked full-time two and three years before the flood, and log daily wages in each of the four years before the flood.

[7] Appendix Tables A14–A16 show that the results are robust to raising this threshold to 20 or 50 directly affected workers per municipality.

The characteristics of the treated worker, such as the exposure type and the damage grade, are assigned to the matched pair. Appendix Table A2 shows that, in the year before the 2021 flood, treated and control workers are close in demographics and wage histories, with small differences in tenure and establishment size; Appendix Tables A5 and A6 show the balance for 2013 and 2002.

5.3 Estimation

Event studies For each flood f and group g (indirectly or directly affected workers), we estimate

$$y_{it} = \alpha_i + \lambda_{p(i),t} + \sum_{k \neq -1} \beta_k^{fg} D_i \cdot \mathbb{1}[t - T_f = k] + \varepsilon_{it}, \tag{5}$$

where y_{it} is the outcome of worker i in year t, D_i indicates the treated worker of a matched pair, T_f is the year of the flood, α_i are worker fixed effects and $\lambda_{p(i),t}$ are matched-pair-by-year fixed effects. The pair-by-year effects compare each treated worker with his or her own matched control in every year, so that β_k^{fg} is the average difference between treated and control workers in event year k relative to the year before the flood. We include event years -3 to $+3$ for 2021 and -3 to $+5$ for 2002 and 2013. Standard errors are clustered at the level of the treated municipality, which allows for correlation among workers affected by the same local shock. By construction of the sample, employment equals one for all workers in the years just before the flood; these event years carry no information and are shown as zero.

Average effects To summarize the event studies, we estimate the static version of (5), replacing the event-year indicators by $D_i \cdot \mathbb{1}[t > T_f]$ and leaving out the flood year itself, in which outcomes mix the periods before and after the flood (Table 2). To test whether directly and indirectly affected workers fare differently, we estimate both groups in one regression and interact the treatment indicator with an indicator for direct exposure. Effects by exposure type are estimated in separate regressions on the pairs of each group G^g in (4); they correspond to the effects τ_0, τ_W, τ_H and τ_B in (2). Effects by damage grade are estimated in the same way.

Channels Employment and the indicators for the channels of non-employment add up to one for every worker and year. Estimating (5) for each channel indicator therefore decomposes the employment effect in a given year into the contributions of closures, mass layoffs, sick leave, retirement, leaving the data, unemployment benefits and other non-employment (Table 3).

Individual difference-in-differences For heterogeneity analyses and the comparison of floods, we follow Schmieder et al. (2023) and construct an individual-level difference-in-differences estimate for each matched pair. For treated worker i and his or her matched control $c(i)$,

$$\Delta_{dd}\, y_i \;=\; \big(\bar{y}_{i,\text{post}} - \bar{y}_{i,\text{pre}}\big) \;-\; \big(\bar{y}_{c(i),\text{post}} - \bar{y}_{c(i),\text{pre}}\big), \tag{6}$$

where $\bar{y}_{\text{pre}}$ and $\bar{y}_{\text{post}}$ are the mean outcomes in the years before (-4 to -1) and after ($+1$ to $+3$) the flood; the same windows apply to all three floods. We then regress this individual effect on worker characteristics,

$$\Delta_{dd}\, y_i \;=\; \alpha + X_i'\gamma + \varepsilon_i, \tag{7}$$

where X_i contains the characteristics of interest and state fixed effects. With indicators for subgroups in X_i, (7) gives the heterogeneity estimates in Appendix Table A13.

Comparing floods Differences between the floods can reflect who was affected or the floods themselves. We use two complementary approaches. First, we reweight the workers affected in 2021 to the characteristics of those affected in 2013 (West Germany only) or 2002, using propensity-score odds weights (DiNardo et al., 1996), an approach that Illing et al. (2024) apply to compare the earnings losses of displaced women and men. The weights are based on gender, age, wages, tenure, days worked and days unemployed, full-time status, education, the county unemployment rate, the flood-risk share of the residence municipality, outside options and the municipality type; workers with a propensity score above 0.95 are excluded. Second, we pool the individual effects $\Delta_{dd}\, y_i$ of two floods and decompose the gap between 2021 and the earlier flood into the contributions of observable characteristics, and report the gap adjusted for these characteristics with a double-selection lasso (Belloni et al., 2014). With only three floods, the remaining gap reflects the context of each flood as a whole and cannot be attributed to single factors.

5.4 Identification

Our estimates identify the effect of the flood if, in its absence, the outcomes of treated workers would have evolved like those of their matched controls. The matching on employment and wage histories makes this plausible for the years before the flood, and the event studies allow us to check pre-trends for all outcomes with variation before the flood. For 2021, the year before the flood was the first year of the COVID-19 pandemic; we therefore also use 2019 as the reference year (Appendix Figure A13).

Two threats are specific to our setting. First, workers who live or work inside a flood zone may differ from other workers in ways that matching on labor market histories does not capture. A spatial regression discontinuity design compares treated workers just inside and just outside the border of the flooded area within the same municipalities, using the individual change in outcomes as the dependent variable (Appendix Figure A11 and Appendix Table A24). Second, control workers may be affected by spillovers. Controls come from other counties, and the results hold when we use only controls from other federal states. Appendix Tables A14–A16 collect this and further robustness checks: stricter thresholds for the number of affected workers per municipality, excluding municipalities with a high ex-ante flood risk or big cities, individual and year fixed effects only, standard errors clustered by county, and, for 2021, a pre-flood period without the year 2020.

6 Results

We first present the effects of the 2021 flood for indirectly and directly affected workers. We then split the directly affected workers by type of exposure and by the severity of the damage, study the channels behind the employment losses, and ask which workers are affected most. The last subsection compares the 2021 flood with the floods of 2013 and 2002.

6.1 The 2021 flood: indirectly and directly affected workers

Figure 2 shows event studies for the 2021 flood, and Panel A of Table 2 reports the average effects over the three years after the flood. Before the flood, the outcomes of treated workers and their matched controls move closely together. After the flood, directly affected workers lose EUR 817 in annual earnings (s.e. 268), about 2.2% of the earnings of their matched controls in the year before the flood, and are 1.7 percentage points (s.e. 0.7) less likely to be employed. Indirectly affected workers lose less: their employment falls by 0.6 percentage points (s.e. 0.2), and their earnings loss of EUR 150 is not statistically significant. The difference between the two groups amounts to EUR

667 for earnings ($p = 0.07$) and 1.1 percentage points for employment ($p = 0.14$). In line with the framework, directly affected workers thus fare worse than indirectly affected workers, although the difference is estimated with limited precision.

The losses of directly affected workers appear in the first year after the flood and persist over the three years we observe. The losses of indirectly affected workers are small at first and build up gradually. We find no effects on the daily wage of workers who remain employed, for either group. The earnings losses therefore reflect less employment rather than lower wages: directly affected workers work 4.9 fewer days per year (s.e. 1.6) and 9.4 fewer days in full-time jobs (s.e. 1.3), compared with 2.2 and 0.8 fewer days for indirectly affected workers (Appendix Table A20). Appendix Figure A6 shows event studies for further outcomes, including marginal employment, unemployment benefits and moves between municipalities, counties, occupations and industries.[8] The wage results are not driven by selection into employment: they are similar for pairs of workers who are employed in every year (Appendix Figure A12).

Municipality-level exposure These results show why the definition of exposure matters. If we treat all workers in an affected municipality as exposed, as most of the literature does, the estimated earnings loss is EUR 211 (s.e. 130) and the employment loss 0.7 percentage points (Appendix Table A19). Because only 9% of the treated workers are directly affected, the pooled estimate is close to the effect for indirectly affected workers. It misses about three quarters of the earnings loss and more than half of the employment loss of directly affected workers.

Evidence from the border of the flooded area A spatial regression discontinuity design provides an independent check of these results. It uses neither control municipalities nor matching: within the affected municipalities, it compares workers who live just inside the flooded area with workers who live just outside it. This holds fixed what workers in the same neighborhood share, including the selection into flood-prone places, and the estimate corresponds to the difference between workers whose home was flooded and indirectly affected workers. At the border, the change in employment between the years before and after the flood drops by 1.9 to 2.7 percentage points (s.e. 0.8), depending on the bandwidth, and the change in annual earnings by about EUR 1,000, which is precisely estimated only for the narrowest bandwidth (Appendix Figure A11 and Appendix Table A24). These magnitudes are close to those of the matched difference-in-differences design, in which workers whose home only was flooded lose 2.8 percentage points of employment and about EUR 1,600 of earnings relative to indirectly affected workers (Section 6.2). Pre-determined characteristics do not jump at the border, and there are no jumps in the years before the flood (Appendix Figure A15 and Appendix Table A25). For workplaces, we find no discontinuity in the outcomes, in line with the absence of losses for workers whose workplace only was flooded.

Robustness The results are also robust to a range of alternative samples and specifications (Appendix Table A14; Appendix E lists all robustness checks): stricter thresholds for the number of directly affected workers per municipality, excluding municipalities with a high ex-ante flood risk or big cities, using only control workers from other federal states, replacing the pair-by-year fixed effects by year fixed effects, clustering standard errors by county, and excluding the year 2020 from

[8] Both groups receive unemployment benefits on about 0.8 more days per year than their matched controls (directly affected workers: s.e. 0.8; indirectly affected workers: s.e. 0.2). Marginal employment hardly changes: the share of directly affected workers whose only job is a marginal one rises by about 0.2 percentage points, and the share with a marginal side job falls slightly, both without statistical significance. Workers who lose their job after the flood thus do not move into marginal employment, and only part of them claims unemployment benefits.

the pre-flood period. The estimates also change little when we use 2019 instead of 2020 as the reference year (Appendix Figure A13).

Comparison with the literature Appendix Tables A30 and A31 compare our estimates with studies of natural disasters and of job loss. Our estimates refer to the average over the first three years after the flood, while most studies report effects for single years, so the comparison is approximate. Our estimates lie at the lower end of those for natural disasters. After Hurricane Katrina, residents of the affected areas lost 3 to 10% of their earnings in the first year, but earned more than comparable workers three years later (Deryugina et al., 2018; Groen et al., 2020). Workers whose home or workplace lay in a block with major damage lost 15 to 17% of their earnings in the first year (Groen et al., 2020); in our setting, workers whose home was flooded lose about 5% per year. Two differences stand out. First, we find no gains for indirectly affected workers within three years. Second, while workplace damage led to large initial losses after Katrina, workers whose workplace only was flooded show no losses in our setting. That the losses are smaller than after Katrina likely reflects both the size of the shock, as Katrina flooded most of New Orleans and displaced much of its population for months, and the German social insurance system, in particular short-time work, which allowed flooded establishments to keep their workers. Compared with job loss, the losses are an order of magnitude smaller: displaced workers lose 25 to 39% of their earnings in the first year after job loss and still 12 to 27% three years later (Jacobson et al., 1993; Couch and Placzek, 2010; Davis and von Wachter, 2011; Lachowska et al., 2020; Fackler et al., 2021; Schmieder et al., 2023). The losses of indirectly affected workers, in turn, are close to those of workers in regions hit by a mass layoff who were not displaced themselves (Gathmann et al., 2020).

6.2 Type of exposure and severity of the damage

The framework implies that the effects depend on how a worker is exposed. The left column of Figure 3 and Appendix Table A10 show that the losses of directly affected workers are concentrated among workers whose home was flooded. Workers whose home only was flooded lose EUR 1,769 in annual earnings (s.e. 371) and are 3.4 percentage points (s.e. 1.0) less likely to be employed. Workers whose home and workplace were both flooded lose EUR 1,093 (s.e. 153) and 4.0 percentage points (s.e. 0.7). In contrast, workers whose workplace only was flooded show no losses: their earnings change by EUR +140 (s.e. 318) and their employment by +0.8 percentage points (s.e. 0.7). The absence of losses for workplace-only workers contradicts the first implication of the framework; Section 6.3 shows that these workers are more often laid off but find new jobs quickly. The pattern is also in line with the regression discontinuity estimates in Section 6.1, which show a drop at the border of the flooded area for residences but not for workplaces.

The right column of Figure 3 splits directly affected workers by the damage grade of their flooded home or workplace. As the framework implies, losses rise with the damage. Workers in assessed areas whose building has no recorded damage lose about 0.8 percentage points of employment and EUR 270 in earnings per year. Workers whose building was graded as possibly damaged, or as damaged or destroyed, lose about 2.4 percentage points and EUR 1,100 to 1,200. We see no further increase between the two higher damage grades, which may reflect that the grading from aerial images separates damaged from undamaged buildings better than degrees of damage (Appendix Table A9 reports the number of workers by damage grade). Appendix Figure A8 shows the same splits for days worked and for changes of establishment.

6.3 Channels: disruption, reallocation and stimulus

Channels of non-employment Table 3 decomposes the employment effect in the first year after the flood into channels of non-employment. For directly affected workers, employment falls by 1.8 percentage points. Mass layoffs account for 40% of this loss and establishment closures for a further 5%. Sick leave accounts for 12% and retirement for 9%; the remainder consists of workers who receive unemployment benefits (18%) or are otherwise without a job (17%). Labor demand thus plays at least as large a role as labor supply. The split between the two depends on how workers who meet the conditions of several channels are assigned: if sick leave takes priority over mass layoffs, mass layoffs account for 31% and sick leave for 22% of the loss (Appendix Table A12). It also differs by type of exposure: mass layoffs are concentrated among workers whose workplace was flooded, sick leave and retirement among workers whose home was flooded (Appendix Table A11). Appendix Figure A7 shows the event studies for closures, mass layoffs and sick leave over time, and Appendix Figure A14 those for the remaining channels.

Channels by type of exposure As the third implication of the framework predicts, the channels differ by how workers were exposed (Appendix Table A11). For workers whose home only was flooded, employment falls by 1.7 percentage points (s.e. 1.2) in the first year after the flood. Sick leave and retirement each account for 23% of this loss, while mass layoffs account for 9% and establishment closures for none. The losses of home-exposed workers thus run mainly through labor supply. Layoffs, in contrast, concentrate among workers whose workplace was flooded. Workers whose home and workplace were both flooded lose 4.1 percentage points of employment (s.e. 0.8); mass layoffs account for a third of this loss, and workers who receive unemployment benefits for a further quarter. Workers whose workplace only was flooded are 0.9 percentage points (s.e. 0.5) more likely to be without a job after a mass layoff and 0.2 percentage points more likely after an establishment closure. These separations, however, do not add up to a significant employment loss: employment falls by 0.7 percentage points (s.e. 1.0) in the first year, and the average effect over three years is zero (Appendix Table A10). Displaced workers whose home stayed dry thus appear to find new jobs quickly. In terms of the conceptual framework, workplace exposure can lead to layoffs, but the resulting employment losses are small when displaced workers find new jobs quickly. Two features of the 2021 flood favor this: the flooded areas were small relative to the surrounding labor markets, and short-time work allowed flooded establishments to keep their workers during repairs, whereas it was not available for workers who were affected only through their home (Section 3). The large share of mass layoffs in the pooled decomposition in Table 3 therefore reflects workers whose workplace was flooded.

Reallocation and stimulus Figure 5 and Appendix Table A21 show how workers move between establishments after the 2021 flood; Appendix Tables A22 and A23 report the same outcomes for the floods of 2013 and 2002. Directly affected workers are 3.7 percentage points (s.e. 1.3) less likely to work at their baseline establishment, compared with 1.9 percentage points for indirectly affected workers. Part of this reallocation is upward: both groups are more likely to have moved to an establishment that pays higher wages (by 1.0 and 0.7 percentage points), while moves to lower-paying establishments do not increase. The framework allows for moves in both directions: displaced workers can move down the job ladder, as in the literature on job loss, while the demand from rebuilding creates vacancies, also at establishments that pay more. That only upward moves increase suggests that the rebuilding stimulus added better jobs, and is consistent with displaced workers finding new jobs quickly. Both groups are also more likely to have entered the construction sector (by 0.3 and 0.1 percentage points), which is where the framework locates the stimulus from

rebuilding. These gains are small, however, and they do not offset the losses: the employment of indirectly affected workers falls over time, suggesting that negative local spillovers outweigh the positive effects from reconstruction during our observation window. The slow payout of the reconstruction funds after 2021 (Section 3) is one possible explanation for the absence of positive net local employment effects.

6.4 Mobility and migration

A flood may also change where people live and work. Studies of large disasters in the United States find substantial out-migration from the affected areas (Deryugina et al., 2018; Groen et al., 2020). We find that the floods in Germany led mainly to local moves (Appendix Table A20 and Appendix Figure A6). Directly affected workers are 2.2 to 2.7 percentage points more likely than their matched controls to live in another municipality in the first two years after the 2021 flood, and 1.2 percentage points more likely in the third year. Most of these moves stay within the county: the probability of living in another county rises by only about half a percentage point in the first year after the flood and returns to zero afterwards, and the average effect over the three years is close to zero (0.2 percentage points, s.e. 0.3). The pattern is consistent with households that leave their damaged homes temporarily or for good, but stay in the region. Among directly affected workers, moves of residence are largest for workers younger than 30 (4.5 percentage points, imprecisely estimated) and smaller but precisely estimated for workers aged 50 or older (2.0 percentage points, s.e. 0.6; Appendix Table A26, Panel B).

Changes of the workplace are small. Indirectly affected workers are 1.2 percentage points more likely to work in another municipality (s.e. 0.6) and 0.7 percentage points more likely to work in another industry (s.e. 0.3), in line with the reallocation across establishments in Section 6.3. For directly affected workers, these effects are similar but not significant, and they are even 0.9 percentage points (s.e. 0.4) less likely to work in another county, which reflects that many of them are not employed. Among indirectly affected workers, younger workers are more likely to take up a job in another county (3.2 percentage points for workers younger than 30), whereas workers aged 50 or older are not (Appendix Table A26). Taken together, the floods did not trigger a large-scale outflow of workers from the affected regions: older workers withdraw from the labor market, and younger workers adjust by changing jobs.

6.5 Which workers are affected most

The average effects hide large differences between workers (Appendix Table A13). The losses are concentrated among older workers. Directly affected workers aged 50 or older are 5.7 percentage points (s.e. 0.6) less likely to be employed and lose EUR 3,233 (s.e. 192) in annual earnings; for indirectly affected workers of this age, the losses are 3.3 percentage points and EUR 1,991. Younger workers do not lose. Similarly, losses increase with tenure and are largest for workers who had been with their employer for ten years or more. For workers aged 50 or older, retirement accounts for 26% of the employment loss of the directly affected and 38% of that of the indirectly affected, next to mass layoffs with 35% and 10% (Table 3, Panel B, and Appendix Table A26). Losses are similar for women and men. By industry, directly affected workers lose most in public administration, education and health and in trade, whereas workers in construction and in hospitality show no losses.

6.6 Comparing the three floods

Panels B and C of Table 2 report the effects of the floods of 2013 and 2002 (event studies in Appendix Figures A2, A3, A4 and A5). The pattern differs from 2021. After the 2013 flood, directly affected workers are 1.1 percentage points (s.e. 0.4) less likely to be employed, but we find no effects on earnings for either group and no effects for indirectly affected workers. After the 2002 flood, indirectly affected workers gain: their earnings rise by EUR 383 (s.e. 65) and their employment by 1.1 percentage points (s.e. 0.1), and directly affected workers do not lose. The 2002 flood is thus the case in which the stimulus appears to dominate.

Differences between the floods can reflect who was affected or the context of the flood. Figure 4 addresses the first explanation. When we reweight the workers affected in 2021 to the characteristics of the workers affected in 2013 or 2002, the losses largely disappear. For directly affected workers, the reweighted earnings effect is small in the first year after the flood and positive in the second and third year, and the reweighted employment effect is no longer negative from the second year on (Appendix Figure A9). The same holds for indirectly affected workers.

Table 4 shows which characteristics matter. For directly affected workers, the individual employment effect of 2021 is 2.8 percentage points lower than that of 2002 and 0.9 percentage points lower than that of 2013. Differences in worker and regional characteristics account for almost all of the gap to 2002: conditional on characteristics, the gap is -0.2 percentage points (s.e. 0.7). They more than account for the gap to 2013, where the adjusted gap is $+1.6$ percentage points (s.e. 0.8). Age is by far the most important characteristic, with contributions of -1.9 and -1.2 percentage points: the workers affected in 2021 are older than those affected by the earlier floods, and older workers lose more. The county unemployment rate comes second. For indirectly affected workers, characteristics account for most of the gap to 2002, but a gap of -0.5 percentage points (s.e. 0.2) remains. The results for earnings are similar, although for directly affected workers part of the gap to 2013 remains (Appendix Table A17).

Taken together, the composition of the affected workforce explains a large part of why the 2021 flood had more negative effects than the earlier floods. The remainder reflects the context of the floods as a whole: the 2021 flood caused more severe damage with less warning, hit more private homes, and was followed by aid that was smaller relative to the damage in the first months and paid out more slowly (Section 3). With three floods, we cannot separate these factors from each other.

7 Conclusion

This paper studies the labor market effects of three large floods in Germany with administrative data in which the homes and workplaces of workers are geocoded. This allows us to separate workers whose home or workplace was flooded from workers who only lived or worked in an affected municipality, and to compare both groups with matched workers in unaffected municipalities.

Three findings stand out. First, exposure has to be measured where it occurs. After the 2021 flood, directly affected workers lose about 2% of their annual earnings and are 1.7 percentage points less likely to be employed, while indirectly affected workers lose much less. Because few workers in an affected municipality are directly affected, a municipality-level definition of exposure misses most of these losses. Second, it matters how a worker is exposed. The losses are concentrated among workers whose home was flooded and rise with the damage to the building, whereas workers whose workplace only was flooded show no losses on average. The channels differ as well: a flooded home keeps workers from work through sickness and early retirement, while a flooded workplace leads to layoffs, from which workers whose home stayed dry recover quickly. Third, the effects of floods depend on their context. The floods of 2013 and 2002 had smaller or even positive effects, and the

composition of the affected workforce explains a large part of the difference to 2021. Compared with job loss, the shock is moderate: the earnings losses of workers hit by the flood are an order of magnitude smaller than those of displaced workers.

These findings have implications for disaster relief. Public aid after floods is tied to damaged buildings and compensates households and firms for their material losses. Our results suggest that the labor market consequences deserve attention of their own, and that they arise where aid programs do not look for them: among workers whose home was flooded but whose employer may not have been affected at all. Measures that preserve existing jobs while households rebuild, such as short-time work or leave arrangements for affected workers, and support that shortens the time workers spend on repairs and paperwork, address this channel more directly than compensation alone. The slow payout of reconstruction aid after 2021 also matters: we find no sign of the stimulus that followed earlier floods.

Floods are not job loss: for most affected workers, the labor market consequences are moderate and temporary. But for workers whose homes are flooded, a natural disaster can turn into a labor market shock of its own.

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Tables

Table 1: Characteristics of treated workers by exposure type, 2021

		Directly affected			
	Indirectly affected	Home only	Workplace only	Home and workplace	All
Panel A: Demographics					
Female	0.46	0.45	0.51	0.59	0.50
Age	46.9	47.6	46.7	47.8	47.3
Tenure (years)	10.3	10.3	10.3	11.4	10.5
Log daily wage	4.62	4.60	4.42	4.20	4.46
Full-time	0.73	0.73	0.65	0.63	0.68
Vocational training	0.74	0.77	0.79	0.81	0.79
University degree	0.19	0.17	0.14	0.10	0.15
Panel B: Firm type (establishment in the year before the flood)					
Log number of employees	4.66	4.66	3.88	3.52	4.13
Fewer than 10 employees	0.12	0.10	0.15	0.23	0.14
10–49 employees	0.23	0.24	0.35	0.34	0.30
50–249 employees	0.29	0.33	0.30	0.24	0.30
250 or more employees	0.36	0.33	0.20	0.19	0.25
Full-time share of employees	0.64	0.61	0.52	0.51	0.56
Log median daily wage, full-time employees	4.78	4.75	4.63	4.51	4.66
AKM establishment effect	0.04	0.03	-0.03	-0.08	-0.01
Number of treated workers	51,361	2,015	2,356	796	5,167

Notes: Means of the characteristics of treated workers in the year before the 2021 flood, by exposure type. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Directly affected workers by exposure type as in equation (4): residence only, workplace only, or both inside the flooded area; "All" pools them. Workers whose residence and workplace were both flooded enter both the residence- and the workplace-matched sample but are counted once per column. Female: share of women. Age in years. Tenure: years with the employer. Log daily wage of the main job. Full-time: share in full-time employment. Vocational training and university degree: shares by the highest degree (imputed education). Panel B: establishment of the employer in the year before the flood. Number of employees, size classes, full-time share of employees and median daily wage of full-time employees from the Establishment History Panel (BHP), on 30 June. AKM establishment effect: establishment fixed effect of the employer from AKM wage regressions (Lochner and Wolter, 2025). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table 2: Average post-flood effects: indirectly vs. directly affected workers

	Indirectly affected		Directly affected		Direct minus indirect	
	Effect	Ctrl. mean (baseline)	Effect	Ctrl. mean (baseline)	Difference [p-value]	Treated (ind./dir.)
Panel A: 2021 flood						
Total yearly earnings (EUR)	-150.0 (146.9)	43302.4	**-816.8 (267.6)**	36708.7	-666.9 (348.5) [0.068]	55,042 / 5,583
Employment	**-0.006 (0.002)**	1.000	**-0.017 (0.007)**	1.000	-0.011 (0.007) [0.140]	
Log daily wage	0.005 (0.004)	4.607	-0.008 (0.006)	4.457	-0.013 (0.009) [0.133]	
Panel B: 2013 flood						
Total yearly earnings (EUR)	93.5 (113.9)	32618.1	135.9 (305.6)	32300.8	42.4 (335.6) [0.900]	201,703 / 7,088
Employment	0.001 (0.001)	1.000	**-0.011 (0.004)**	1.000	**-0.013 (0.004)** [0.007]	
Log daily wage	0.004 (0.003)	4.367	0.003 (0.006)	4.336	-0.001 (0.008) [0.911]	
Panel C: 2002 flood						
Total yearly earnings (EUR)	**383.3 (64.7)**	31762.7	214.3 (188.1)	28647.9	-169.0 (177.3) [0.342]	236,184 / 23,571
Employment	**0.011 (0.001)**	1.000	0.006 (0.003)	1.000	-0.005 (0.003) [0.096]	
Log daily wage	0.002 (0.002)	4.378	-0.000 (0.006)	4.268	-0.002 (0.005) [0.656]	

Notes: Effects: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +3 for the 2021 flood and −3 to +5 for the floods of 2002 and 2013, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Yearly earnings: earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job. Employment: employed on the reference date in each year, the same calendar day as the day before the flood; by construction of the sample, all workers are employed before the flood. Log daily wage: daily wage of the main job, observed for employed workers only. Control mean (baseline): mean of the matched controls on the reference date, the day before the flood, for status outcomes and in the calendar year before the flood for yearly earnings and days worked. Direct minus indirect: coefficient on the interaction of treated × post-flood with direct exposure in one regression for both groups; p-value of the test of equality in brackets. Coefficients and standard errors in bold are significant at the 5% level (difference: p-value below 0.05). Treated: number of indirectly / directly affected treated workers. Further outcomes: Appendix Table A20. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table 3: Decomposition of the employment effect by channel (year +1): all workers and workers aged 50+

	Indirectly affected		Directly affected	
	Effect (pp)	Share (%)	Effect (pp)	Share (%)
Panel A: All workers				
Employment effect	-0.38 (0.10)	100	-1.79 (0.83)	100
Mass layoff	0.11 (0.04)	30.1	0.72 (0.22)	40.0
Unemployment benefits	0.06 (0.03)	14.8	0.32 (0.13)	18.0
Other, still in the data	0.16 (0.10)	42.6	0.30 (0.20)	17.0
Sick leave	0.06 (0.03)	15.3	0.21 (0.28)	12.0
Retirement	0.00 (0.04)	0.5	0.16 (0.24)	9.0
Establishment closure	0.00 (0.01)	0.5	0.09 (0.08)	5.0
Left the data	-0.01 (0.03)	-3.8	-0.02 (0.13)	-1.0
Panel B: Workers aged 50 and older				
Employment effect	-1.40 (0.28)	100	-3.42 (0.76)	100
Mass layoff	0.15 (0.05)	10.5	1.20 (0.35)	35.1
Unemployment benefits	0.13 (0.06)	9.1	0.14 (0.17)	4.1
Other, still in the data	0.51 (0.15)	36.3	0.60 (0.24)	17.5
Sick leave	0.06 (0.09)	4.3	0.46 (0.22)	13.4
Retirement	0.53 (0.08)	38.2	0.88 (0.48)	25.8
Establishment closure	0.00 (0.01)	0.3	0.18 (0.16)	5.2
Left the data	0.02 (0.06)	1.3	-0.04 (0.26)	-1.0

Notes: Decomposition of the employment effect in year +1 (reference date 13 July 2022) into mutually exclusive channels of non-employment, estimated separately for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each non-employed worker is assigned to the first applicable channel in the order establishment closure, mass layoff, sick leave, retirement. Establishment closure / mass layoff: the worker leaves an establishment whose employment falls by at least 90% / 30% between the reference dates of 2021 and 2022, defined from worker flows in the Establishment History Panel, and is not employed in 2022. Sick leave: the employment spell ends with a sickness-related reason code; after six weeks of sickness, the spell subject to social security contributions is interrupted while the employment relationship continues. Retirement: aged 62 or older in 2021 and no record in the data in 2022–2024. The remaining non-employed workers are split into "left the data" (no record in the IEB in that year: self-employment, civil service, moving abroad, death, early or disability pension), "unemployment benefits" (at least one day of unemployment benefit I in the calendar year) and "other, still in the data" (for example, recipients of basic income support only). Workers on short-time work remain employed. Each channel effect is the coefficient for year +1 of equation (5) with the channel indicator as outcome. Employment and the channel indicators add up to one for every worker, so that the channel effects add up to minus the employment effect; shares in percent of the employment effect, which can be negative. Effects in percentage points, standard errors clustered at the treated municipality in parentheses. Rows are ordered by the absolute share of the channel for directly affected workers in Panel A. Panel B: treated workers aged 50 or older in the year before the flood and their matched controls. *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table 4: How much of the employment gap between 2021 and earlier floods is composition?

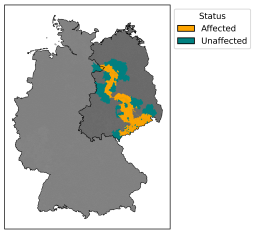
	2021 vs. 2013		2021 vs. 2002	
	Indirect	Direct	Indirect	Direct
Raw gap (pp)	-0.44	-0.87	-1.71	-2.83
Adjusted gap, lasso (pp)	0.17 (0.33)	1.59 (0.83)	-0.48 (0.21)	-0.24 (0.72)
Contribution of differences in:				
Age	-0.73	-1.23	-1.18	-1.90
Log daily wage	0.02	-0.26	0.11	0.06
Tenure	-0.00	-0.09	-0.22	-0.22
Days in unemployment	0.02	0.00	-0.10	-0.17
Days worked	0.00	-0.00	-0.00	-0.02
Female	-0.00	0.17	-0.00	0.00
Full-time	0.02	0.07	0.16	0.21
Education	-0.03	-0.05	-0.13	-0.10
County unemployment rate	-0.30	-0.58	0.00	-0.42
High flood-risk share	-0.00	0.03	0.04	-0.13
Outside options	-0.00	0.02	-0.08	-0.02
Municipality type	0.50	-0.17	-0.03	0.01
Sum of contributions	-0.50	-2.08	-1.44	-2.70

Notes: Gap: average individual effect of workers affected in 2021 minus that of workers affected in the earlier flood, separately for indirectly and directly affected workers. The individual effect of a matched pair, equation (6), is the change in the treated worker's mean outcome between the years before (−4 to −1) and after (+1 to +3) the flood minus the same change for the matched control; the windows are the same for all floods. Contribution of characteristic k: $\hat{\gamma}_k(\bar{x}_k^{2021} - \bar{x}_k^{\text{earlier}})$, where $\hat{\gamma}_k$ is the coefficient from one regression of the individual effects of both floods on all characteristics, equation (7); contributions are summed within the groups shown and need not add up to the raw gap. Adjusted gap: gap conditional on all characteristics, estimated with the double-selection lasso of Belloni et al. (2014); standard errors in parentheses. Tenure: with the employer and in the occupation. Education: indicators for the categories of the imputed education variable. Municipality type: indicators for the BBSR town and municipality type of the residence and the workplace municipality. Outside options: transition-weighted employment in the other occupations of the worker's commuting zone (standardized). Missing characteristics are set to zero and flagged; the flags enter the regressions and the sum of contributions, but are not shown (contributions below 0.01 percentage points). Workers of 2021 with a propensity score above 0.95 in the reweighting to the earlier flood are excluded. The comparison with 2013 uses workers in West Germany only. Outcome: employment. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

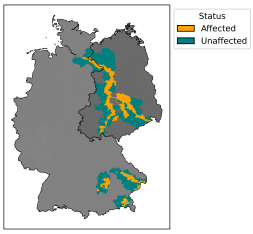
Figures

Figure 1: Affected municipalities and treatment assignment

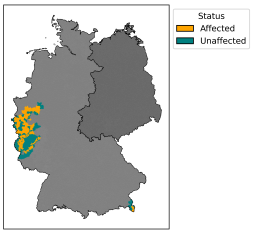
(a) 2002 flood: affected municipalities



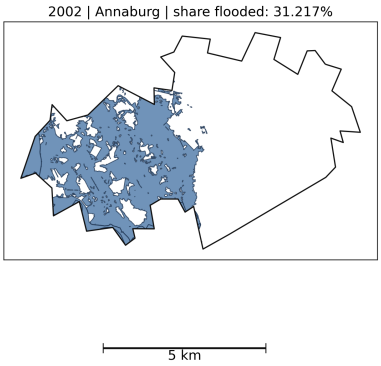
(b) 2013 flood: affected municipalities



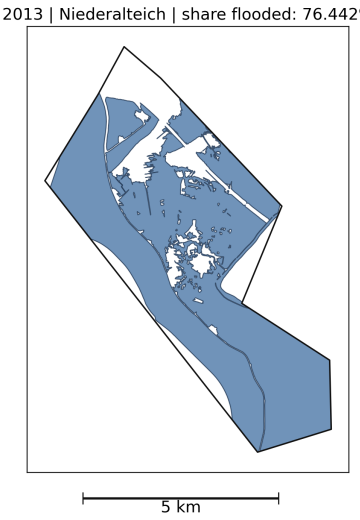
(c) 2021 flood: affected municipalities



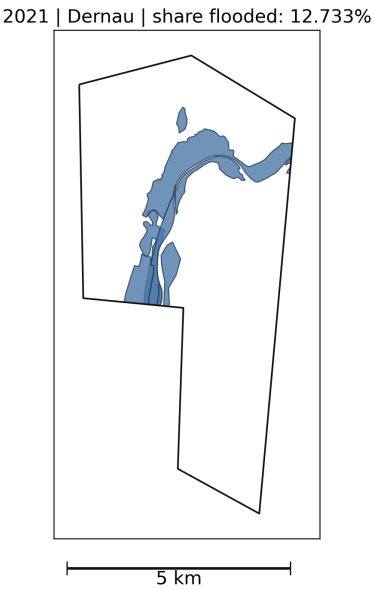
(d) 2002: Annaburg (31.2% flooded)



(e) 2013: Niederalteich (76.4% flooded)

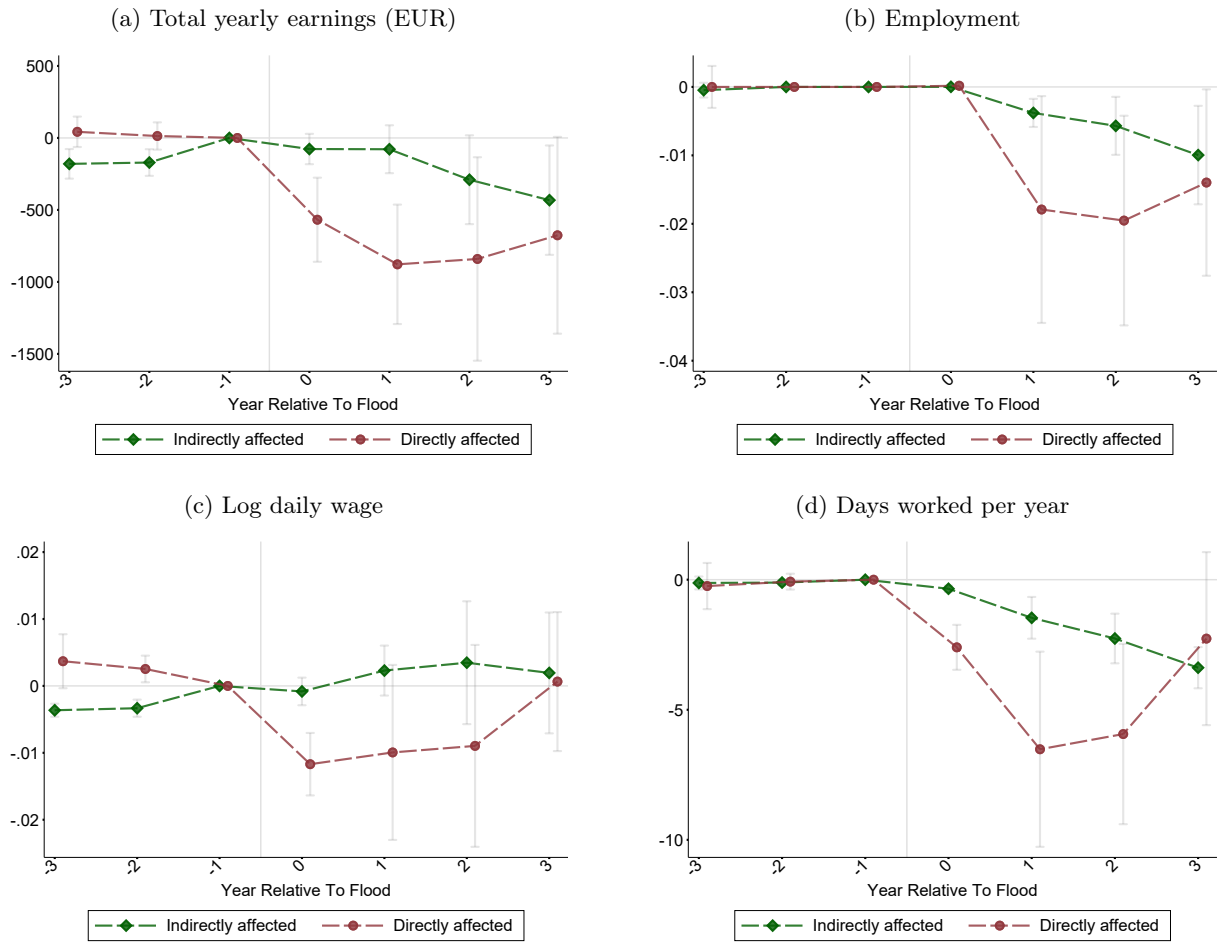


(f) 2021: Dernau (12.7% flooded)



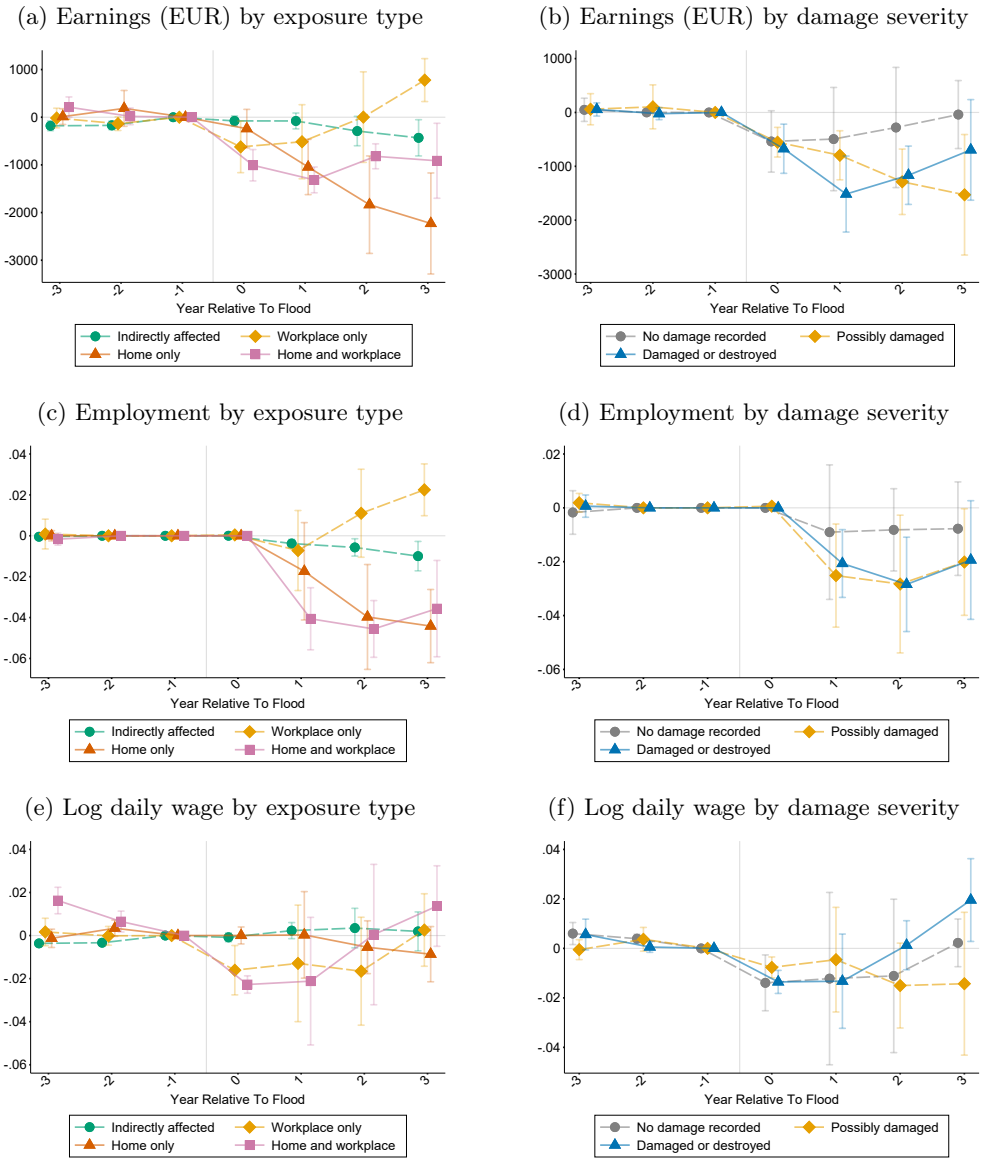
Notes: Panels (a)–(c): municipalities in the counties hit by each flood; municipalities with a non-zero flooded area (affected) in orange, the other municipalities of these counties in teal. Panels (d)–(f): one affected municipality per flood (black outline) with its flooded area (blue) and the share of the municipal area that was flooded. Workers who live or work in an affected municipality are treated ($D_i = 1$ in equation (4)). Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. *Source:* flood-extent maps; administrative boundaries © GeoBasis-DE / BKG; own illustration.

Figure 2: Effects of the 2021 flood: indirectly vs. directly affected workers



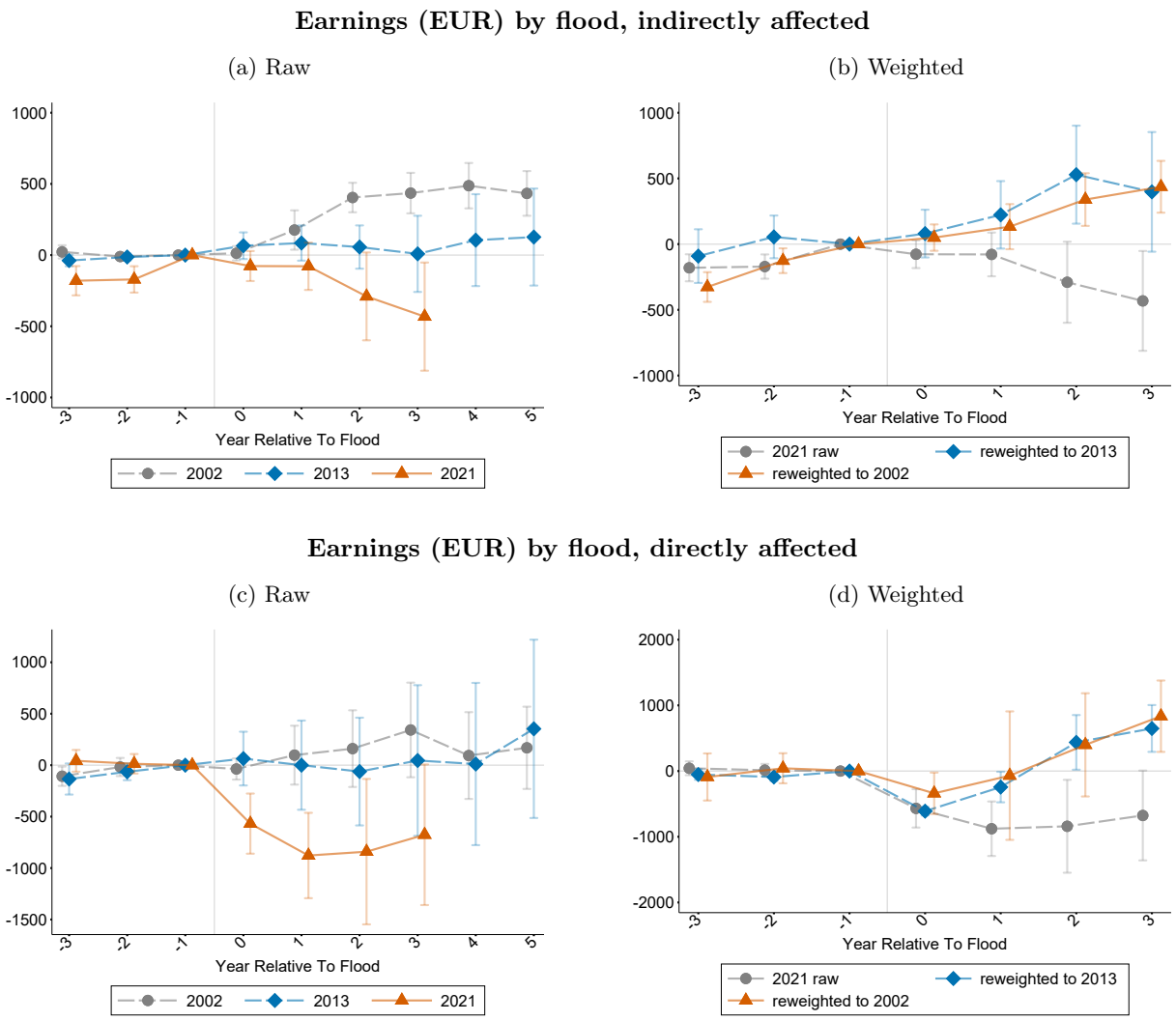
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. 2021 flood. Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Yearly earnings: earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job. Employment: employed on the reference date in each year, the same calendar day as the day before the flood. Log daily wage: daily wage of the main job, observed for employed workers only. Days worked: days in employment subject to social security contributions in the calendar year. By construction of the sample, all workers are employed before the flood; event years without variation in the outcome are shown at zero without confidence interval. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure 3: Event studies by exposure type and damage severity



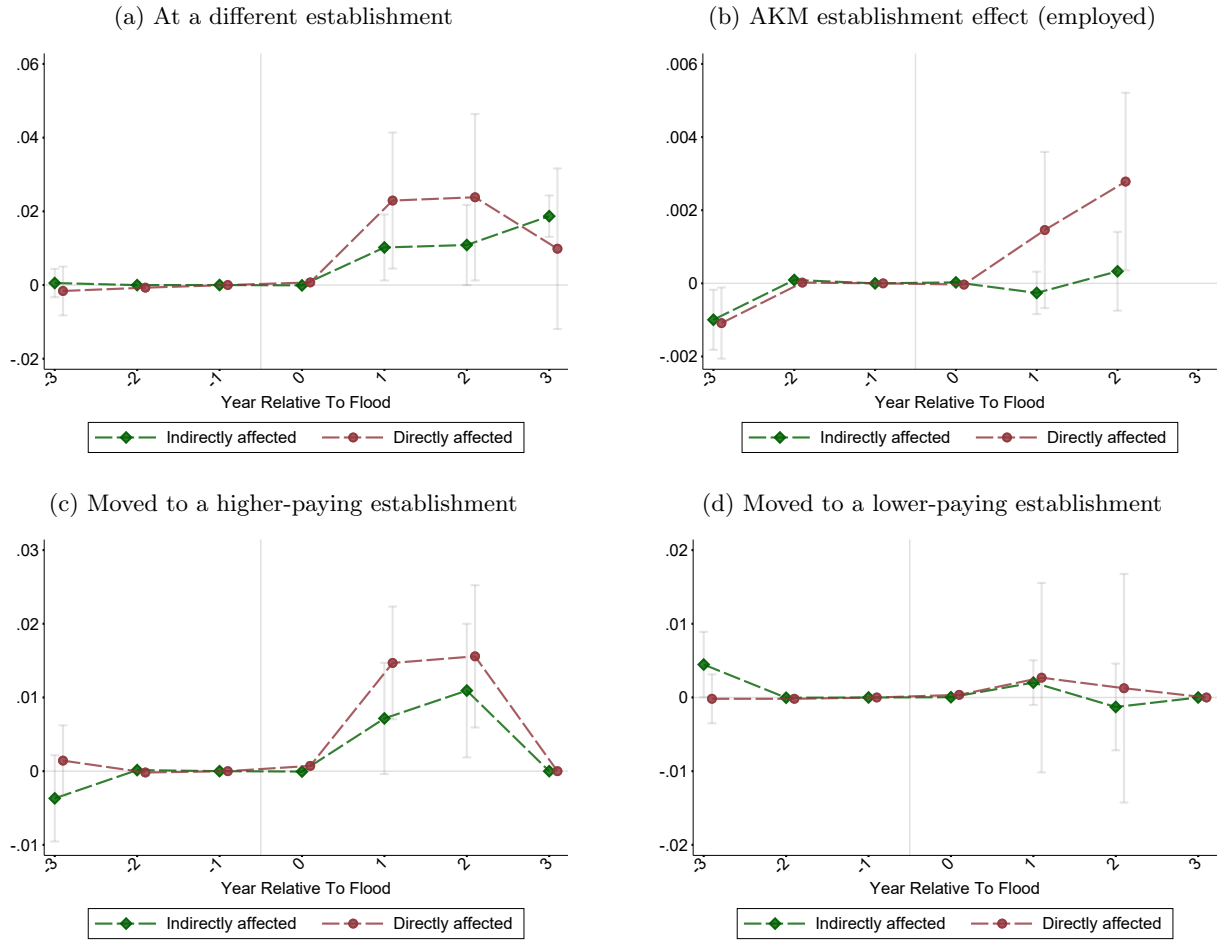
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. 2021 flood. Left column, panels (a), (c) and (e), exposure type: Exposure types as in equation (4): indirectly affected; directly affected at the workplace only, at home only, or both. Each type is estimated in a separate regression on its matched pairs; the estimates correspond to τ_0, τ_W, τ_H and τ_B in equation (2). The exposure type of the treated worker applies to the matched pair. Types with fewer than 30 treated workers or 8 treated municipalities are not shown. Right column, panels (b), (d) and (f), damage severity: directly affected workers by the Copernicus damage grade of their flooded residence (residence-matched pairs) or workplace (workplace-matched pairs). A place receives the grade of the nearest graded building within 10 meters; "no damage recorded": inside an area assessed by Copernicus, but no graded building within 10 meters; "damaged or destroyed" combines the two highest grades (only 15 treated workers live or work in a destroyed building). Directly affected workers outside the assessed areas are not used. Treated workers: indirectly affected 55,042; workplace only 2,357; home only 2,015; both 1,207; no damage recorded 2,327; possibly damaged 1,590; damaged or destroyed 1,548. Yearly earnings: earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job. Employment: employed on the reference date in each year, the same calendar day as the day before the flood. Log daily wage: daily wage of the main job, observed for employed workers only. Days worked: days in employment subject to social security contributions in the calendar year. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps, Copernicus EMS damage grading (EMSR517).

Figure 4: Earnings effects across floods: event studies by flood and after reweighting



Notes: All panels show event-study coefficients β_k of equation (5) for yearly earnings (earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job), with 95% confidence intervals; individual and matched-pair × year fixed effects; reference year −1; standard errors clustered at the treated municipality. Upper row: indirectly affected workers (residence or workplace in an affected municipality, but outside the flooded area); lower row: directly affected workers (residence or workplace inside the flooded area). Raw, panels (a) and (c): the floods of 2002 (gray), 2013 (blue) and 2021 (orange), each relative to its own matched controls; event years −3 to +5 (+3 for 2021). Weighted, panels (b) and (d): the 2021 flood, unweighted and reweighted. Reweighted series: workers affected in 2021, reweighted to the characteristics of the workers affected in 2013 (West Germany only) or in 2002 with propensity-score odds weights (DiNardo et al., 1996). The weights are $\hat{p}/(1-\hat{p})$, where $\hat{p}$ is the predicted probability of belonging to the earlier flood from a probit on gender, age, log daily wages, tenure, days worked and days unemployed, full-time status, education, the county unemployment rate, the flood-risk share of the residence municipality, outside options and the municipality type; workers with $\hat{p} > 0.95$ are excluded. Balance after reweighting: Appendix Table A7. Employment: Appendix Figure A9; log daily wage: Appendix Figure A10. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure 5: Firm reallocation, 2021: indirectly vs. directly affected workers



Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals for the 2021 flood, from regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; standard errors clustered at the treated municipality. Indirectly (green) and directly (maroon) affected workers are each compared with their matched controls. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. All outcomes refer to the baseline establishment, the establishment of year −1. Panel (a): employed at an establishment other than the baseline establishment. Panel (b): establishment fixed effect of the current employer from AKM wage regressions estimated on the IEB for 1993–2000, 2001–2008, 2009–2016 and 2017–2023 (Lochner and Wolter, 2025), for employed workers only; because the effects are estimated by period, their levels are comparable only within a period. Panels (c) and (d): employed at a different establishment whose AKM effect is higher (c) or lower (d) than that of the baseline establishment. The indicators in panels (a), (c) and (d) are zero for workers without a job. Further reallocation outcomes, staying at the baseline establishment and entry into construction or the public sector: Appendix Figure A7, panels (d)–(f). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Online Appendix

for

The Labor Market Effects of Flood Events

Hannah Illing Hanna Schwank Johannes Weber Leonie Wicht

November 15, 2026

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A Insurance and public aid: details

Appendix Table A1 compares the three floods. This appendix describes insurance and public aid in more detail. Unless stated otherwise, all amounts are nominal and come from the laws, parliamentary papers and official reports listed in the notes of Appendix Table A1.

Insurance Flood insurance (*Elementarschadenversicherung*) is voluntary in Germany. Insured losses were EUR 1.9 billion in 2002, 1.8 billion in 2013 and 8.6 billion in 2021, a small share of the damage in each case (GDV, 2025). Coverage rose over time: in 2002, only about 4% of residential buildings in Germany were insured against floods, compared with about 46% in 2021 (DKKV, 2003, 2022). The low national figure for 2002 understates coverage in the affected regions, however. Many households in eastern Germany still held the household insurance of the former GDR state insurance, which automatically covered all natural hazards, including floods. After reunification, an Allianz subsidiary took over these contracts, and about 3 million households still held them in 2002. In a survey of flood-damaged households in Saxony and Saxony-Anhalt, half were insured (DKKV, 2003). Building insurance was much rarer than contents insurance.

Emergency aid and reconstruction funds After each flood, the federal government and the states provided public aid in two stages that differ in timing, purpose and size.

- *Emergency aid* (*Soforthilfe*) was paid within days or weeks of the flood. It covered immediate needs: lump-sum payments to households (in 2002 up to EUR 10,000 per household as transitional aid), liquidity aid and hardship grants for firms and the self-employed, aid for farmers, and first measures by municipalities such as clean-up work. The states ran the programs and the federal government paid half. Emergency aid was small relative to the damage: about EUR 1.5 billion in 2002 (13% of the damage), 0.9 billion in 2013 (14%) and 0.8 billion in 2021 (2%) (BMI, 2002; BT-Drs. 17/14743; BT-Drs. 19/32497). It was complemented by tax relief, subsidized loans from public banks, the reimbursement of social security contributions for short-time work (2002 and 2013), and a temporary suspension of the duty to file for insolvency.
- *Reconstruction funds* (*Aufbauhilfefonds*) were special federal funds set up by law within weeks of each flood and financed jointly by the federal government and the states: EUR 7.1 billion in 2002, 8 billion in 2013 and 30 billion in 2021. They financed the rebuilding of damaged homes, businesses and infrastructure. Owners and firms applied after the damage had been assessed, and the funds covered up to 80% of the damage remaining after insurance payments and emergency aid (up to 100% in cases of hardship in 2021, when holding flood insurance was not a condition for aid). Because applications, assessments and approvals took time, the funds paid out slowly: by mid-2016, three years after the 2013 flood, EUR 2.2 billion had been paid out, about a third of the damage; by April 2024, almost three years after the 2021 flood, 3.75 billion had been paid out, about a tenth of the damage (BT-Drs. 18/9354; BT-Drs. 20/14000). The funds were set up before the damage was known; this is why the 2013 fund exceeded the damage estimate and why 3.2 billion of the states' share and 1 billion for federal infrastructure were later returned.

The distinction matters for our analysis because the two instruments operate at different points of the event window. Emergency aid can at most cushion the immediate shock in the year of the flood. The reconstruction funds create demand for construction and related services over several years, and their slow payout after 2021 implies that this stimulus was weaker during our post-flood window than after 2002 and 2013.

Distribution between households, firms and municipalities The sources allow a rough split of the aid by recipient for 2002 and 2013; for 2021, they only allow a split between the states.

- *2002.* Of the emergency aid, about EUR 0.3 billion went to private households, about 1 billion to firms and the self-employed (an emergency program for small and medium-sized firms of 0.4 billion and a hardship fund of 0.6 billion), about 0.06 billion to farmers, and about 0.07 billion to municipalities and employment companies for clean-up work (up to 5,000 jobs) (BMI, 2002). The reconstruction fund was distributed among the states by a fixed key: Saxony received about 79% and Saxony-Anhalt 13%. A split of the fund by recipient is not available.
- *2013.* Of the emergency aid of about EUR 0.9 billion, 0.24 billion went to private households, 0.42 billion to firms and the self-employed, 0.12 billion to agriculture and forestry, and 0.13 billion to municipal infrastructure. The reconstruction fund was split into 1.5 billion for federal infrastructure and 6.5 billion for the states, of which the states earmarked about 0.59 billion for private households and housing companies, 0.53 billion for firms, 0.40 billion for agriculture and forestry, 2.35 billion for municipal infrastructure and 2.64 billion for state infrastructure. By mid-2016, about 2.47 billion had been approved for municipal infrastructure, 0.56 billion for state infrastructure and 0.52 billion for private households and housing companies; firms had applied for 0.45 billion by mid-2015 (BT-Drs. 17/14743; BT-Drs. 18/5641; BT-Drs. 18/9354). Most reconstruction money thus went to public infrastructure, much of it to municipalities.
- *2021.* Emergency aid was organized by the states, with the federal government paying half of up to EUR 0.8 billion. Of the reconstruction fund, 2 billion were reserved for federal infrastructure and 28 billion for the reconstruction programs of the states, distributed by a provisional key: 54.5% to Rhineland-Palatinate, 44.0% to North Rhine-Westphalia, and the rest to Bavaria and Saxony (BMI, 2022). A split by recipient is not available.

B Flood data and geocoded addresses

Flood extent For each flood, we collect maps of the flooded area from public institutions. Comprehensive nationwide data are not available for every flood; we use high-quality maps for the most severely affected federal states, which together cover the large majority of the damage and all key areas. We combine the maps of a flood into one spatial layer and overlay it with the boundaries of municipalities and counties to compute the flooded share of each administrative unit.

- *2002:* Saxony and Saxony-Anhalt. The maps come from the Saxon State Office for Environment, Agriculture and Geology (LfULG) and from the Federal Agency for Cartography and Geodesy (BKG). Institutions in other states could not provide spatial data of the flood extent.
- *2013:* Saxony, Saxony-Anhalt and Bavaria. The maps come from the LfULG (Saxony); from two aerial reconnaissance missions of the Federal Institute of Hydrology (BfG) and from the State Office for Flood Protection and Water Management (LHW) in Saxony-Anhalt, of which we take the union to account for differences in coverage; and from the Office for Water Management in Deggendorf, which documented the flooding along the Danube around Passau (Bavaria). Because the flood boundaries of 2013 are geometrically complex, we simplify the polygons with the Douglas-Peucker algorithm with a tolerance of 10 meters. This reduces the number of coordinates substantially without materially affecting the flooded areas.
- *2021:* North Rhine-Westphalia and Rhineland-Palatinate. All maps come from the Copernicus Emergency Management Service, the satellite-based rapid mapping service of the European

Union, which provided delineation maps of the flooded areas shortly after the event. For 2021, the service also provides the grading of building damage that we use in the damage analysis (Section 4.1). The service also mapped parts of the areas flooded in 2013, in Saxony and Bavaria (activation EMSR044) and, in a later reconstruction, along the lower Elbe (EMSN056). These maps cover selected areas only and contain no grading of building damage; for 2013, we use the maps of the state and federal agencies described above.

Residence The IEB-Geo contain the geocoded addresses of workers' residences and of establishments. For some workers, they contain more than one address record on the reference date, and some geocodes are not precise enough for our analysis. Because our design requires a unique exposure status and a well-defined distance to the flooded area, we select one address per worker in five steps. First, we keep only records whose address is geocoded unambiguously: for 2002 and 2013, records with a unique match of the address; for 2021, records geocoded at the level of the building. Second, for 2021 only, we keep records whose coordinates lie in the municipality of residence recorded in the IEB, which applies to 93% of the records. Third, if a worker has records from different sources, we prefer records from the data on means-tested benefits, which are tied to the address of the household, then records from employment, and then records from other sources; the data on means-tested benefits start in 2005 and therefore play no role for 2002. Fourth, if the remaining records of a worker differ by more than 5 meters in their distance to the flooded area, we drop the worker; otherwise, we keep the record with the smallest distance.[9] Fifth, if several records remain, we keep the one with the most recent start date.

Workplace Workplace addresses are recorded at the level of the establishment. For 2002 and 2013, the data contain one record per establishment, and we keep establishments whose address is matched uniquely. For 2021, we keep records geocoded at the level of the building whose coordinates lie in the workplace municipality recorded in the IEB, which applies to 99% of the records. If an establishment has several such records that differ by more than 5 meters in their distance to the flooded area, we drop it; otherwise, we keep the record with the smallest distance.

C Matching of municipalities

Each affected municipality is matched to one control municipality in the year before the flood (2001, 2012 and 2020). The matched pairs define the cells within which we match workers (Section 5.2).

Pool of potential controls A municipality can serve as a control for a given flood only if (i) it was not flooded in 2002, 2013 or 2021, (ii) no municipality of its county was affected by that flood, (iii) it does not lie in one of the five river basins downstream of the affected areas, and (iv) for 2021, its county is not classified as exposed or severely exposed to the flood by Hoenow et al. (2025), who use the flood mapping of the Federal Office for Civil Protection and Disaster Assistance. Berlin, Hamburg, Munich and Cologne are excluded from the matching.

Matching variables All variables refer to the year before the flood. We match exactly on West Germany, the size class of the municipality (five classes, with cut-offs at 5,000, 50,000, 100,000 and 500,000 inhabitants), an indicator for a median wage above the East- or West-German median,

[9] We do not distinguish between different flooded areas here, so that the difference in the distances to the flood is not a measure of the distance between the two addresses.

and an indicator for a relative economic downturn of the county, based on HP-filtered county GDP relative to the national trend. Within these cells, each affected municipality receives the nearest control without replacement by the Mahalanobis distance. The distance uses, for the municipality, the population, the number of employees at the workplace, the population shares in ten age groups, and the river length relative to the area; for the county, the shares of 17 industries, the population density, the median wage, the unemployment rate, the in- and out-migration rates (five-year means), the settlement type, and the population of the largest municipality.

Dresden and Leipzig For the two largest affected cities, there is no suitable control in East Germany. They are matched separately to West German cities with the same variables, without the exact match on East and West Germany and with the median-wage indicator computed for Germany as a whole. Dresden is matched to Bielefeld (2002) and Bremen (2013), Leipzig to Wiesbaden (2002).

Matched pairs and balance Appendix Table A29 summarizes the matched pairs. We match all 302 affected municipalities of 2002 and all 261 of 2013, and 265 of 266 in 2021. Control municipalities never lie in a county with an affected municipality; between a quarter (2002) and a half (2021) of the pairs lie in the same federal state. Appendix Tables A27 and A28 compare affected and control municipalities in the year before each flood. In 2021, affected and control municipalities have a similar size (about 25,000 and 22,000 inhabitants), the same number of employees and the same density of rivers, and the differences in the age structure are small. The remaining differences concern the county: control municipalities lie in counties with a median daily wage that is EUR 4.4 higher, and the counties of the affected municipalities have higher industry shares in hospitality and lower shares in business services.

D Variables of the employment decomposition

This appendix defines the variables used in the decomposition of the employment effect into channels (Table 3, Appendix Tables A11, A12 and A26). All definitions refer to the 2021 flood; the reference date is 13 July, the day before the flood, in every year.

D.1 Employment and presence in the data

Yearly panel We turn the IEB spell data into one observation per worker and year. If a worker holds several spells on the reference date, we keep the one with the highest daily wage. Workers without any record in a calendar year are added to the panel for that year, so that the panel is balanced.

Employment A worker is *employed* if he or she holds a job on the reference date: an employment spell subject to social security contributions, including marginal jobs, with a positive daily wage. Employment is thus measured at the same date as all other status variables (establishment, daily wage, full-time status, moves).

Presence in the data A worker-year is *in the data* if the IEB contain at least one record for the worker in that calendar year: employment, marginal employment, benefit receipt or registration as a job seeker. In years without any record, employment, earnings and days worked are set to zero.

D.2 Establishment closures and mass layoffs

Closures and mass layoffs are defined at the establishment level from the worker-flow data of the Establishment History Panel (BHP), following the approach of Hethey-Maier and Schmieder (2013). The BHP measure employment on 30 June of each year and, for each establishment and year, the number of workers who leave and the largest number of leavers who move to one single other establishment.

Let E_{jt} be the employment of establishment j on 30 June of year t. An establishment has an *employment drop* between $t-1$ and t if all of the following hold:

1. *Size:* the establishment had at least ten employees in $t-2$.
2. *Size of the drop:* employment falls by at least 30% (mass layoff) or at least 90% (closure), $(E_{j,t-1} - E_{jt})/E_{j,t-1} \geq 0.3$ or ≥ 0.9, and by at least five workers. Closures are a subset of mass layoffs.
3. *No takeover or spin-off:* no single destination establishment absorbs more than 20% of the establishment's outflows. This excludes changes of the establishment identifier, takeovers and spin-offs, in which many workers move together to one successor.
4. *No temporary swings:* employment did not grow by 30% or more in either of the two years before the drop, and it does not recover to 90% of its level in $t-1$ in either of the two years after the drop.

A *displaced worker* is employed at establishment j on the reference date of year t, is not employed on the reference date of year $t+1$, and his or her establishment has an employment drop between t and $t+1$. The worker is assigned to the channel *establishment closure* (drop of at least 90%) or *mass layoff* (drop of at least 30%) in year $t+1$, the first year of non-employment.

Two features of this definition matter for the interpretation. First, the channel is assigned only in the first year of non-employment; a displaced worker who is still not employed one year later moves to one of the remaining channels. In Table 3, which refers to year +1, all displaced workers are captured, because every worker in the sample was employed on the reference date in 2021. Second, the BHP measure employment on 30 June and the IEB on 13 July, so that the drop of an establishment and the job loss of the worker refer to almost, but not exactly, the same dates.

D.3 Sick leave

When a worker receives sickness benefit (*Krankengeld*), which starts after six weeks of sickness, the employer stops paying wages and reports an interruption of the employment subject to social security contributions. Long-term sick workers can therefore appear as not employed on the reference date although their employment relationship continues. We identify such workers from the reason codes with which employment spells end. A worker-year is coded as *sick leave* if the spell kept for that year ends with a sickness-related reason code.

D.4 Retirement

Following Badalyan (2025), we classify a worker as *retired* if he or she was born in 1959 or earlier (aged 62 or older in 2021), was employed on the reference date in 2021, and has no record in the data in 2022, 2023 and 2024. The indicator applies in every post-flood year in which the worker is not employed. Retirement before age 62, including disability pensions, is not observed in the IEB: such workers leave the data and appear in the channel "left the data".

D.5 Remaining non-employment

Non-employed workers who are not assigned to one of the four channels above are split into three groups:

- *Left the data:* no record in the IEB in that calendar year. This includes self-employment, civil service, moving abroad, death, and pensions not covered by the retirement channel (early retirement before age 62, disability pensions).
- *Unemployment benefits:* still in the data and at least one day of unemployment benefit I (*Arbeitslosengeld I*) in the calendar year. Because benefit days are counted over the whole calendar year while employment is measured on the reference date, a worker who received benefits only in the first months of the year and is not employed on 13 July also falls into this group.
- *Other, still in the data:* still in the data, without unemployment benefit I in that year. This includes workers who receive only basic income support (*Arbeitslosengeld II*, *Bürgergeld*), registered job seekers without benefits, and participants in active labor market programs.

Workers on short-time work (*Kurzarbeit*) remain employed in the data and do not enter any channel.

D.6 Assignment and decomposition

Priority A worker-year can meet the conditions of several channels, for example a worker who leaves a closing establishment while on sick leave. Non-employed workers are therefore assigned to the first applicable channel in the order establishment closure, mass layoff, sick leave, retirement; the remaining non-employed workers are split into left the data, unemployment benefits and other. Appendix Table A12 uses the alternative order sick leave, establishment closure, mass layoff, retirement.

Identity For every worker and year, employment and the seven channel indicators add up to one:

$$\text{employed}_{it} + \sum_{c} \text{channel}_{it}^{c} = 1.$$

We estimate the event study (5) with each channel indicator as the outcome and report the coefficient for year +1. By the identity, the channel effects add up to minus the employment effect. The share of a channel is its effect divided by the sum of all channel effects; shares can be negative when treated workers are less likely than their controls to be in a channel.

Age groups For the age groups (Table 3, Panel B; Appendix Table A26), matched pairs are assigned to an age group by the age of the treated worker in the year before the flood.

E Robustness

In this appendix, we show that the effects of the 2021 flood are robust to alternative samples and specifications, to the choice of the reference year, and to a design that does not rely on matching. Unless stated otherwise, the checks refer to the average effects in Table 2, where directly affected workers lose EUR 817 in annual earnings and 1.7 percentage points of employment, and indirectly affected workers lose EUR 150 and 0.6 percentage points.

Sample restrictions Appendix Table A14 repeats the main estimates with one change at a time. In the baseline, we exclude affected municipalities with fewer than ten directly affected workers. When we raise this threshold to 20 or 50 workers, the losses of directly affected workers hardly change (EUR 867 and 1.9 percentage points in both cases), while the small earnings loss of indirectly affected workers shrinks further (EUR 95 and 9). Workers in places with a high ex-ante flood risk may differ from other workers, for example because they have adapted to the risk. Excluding workers whose workplace municipality is in the top decile of the share of area at high flood risk leaves the estimates almost unchanged (EUR 852 and 1.8 percentage points for directly affected workers). The same holds when we exclude workplace municipalities with 230,000 or more employees, where the affected areas make up a small part of a large labor market (EUR 745 and 1.7 percentage points).

Spillovers to control workers If control workers were affected by the flood, for example through commuting or regional supply chains, our estimates would be biased. Control workers come from counties without any affected municipality. When we further restrict the sample to pairs whose control worker lives in another federal state than the treated municipality, the losses of directly affected workers become slightly larger (EUR 882 and 1.8 percentage points) and those of indirectly affected workers stay the same (EUR 155 and 0.6 percentage points).

Specification and inference Replacing the matched-pair-by-year fixed effects by individual and year fixed effects yields identical point estimates. Clustering standard errors at the level of the county instead of the treated municipality increases the standard error of the earnings effect for indirectly affected workers (from 147 to 203), but leaves the effects for directly affected workers statistically significant. For 2021, the year before the flood was the first year of the COVID-19 pandemic. Excluding 2020 from the pre-flood period changes the estimates little (EUR 826 and 1.7 percentage points for directly affected workers). Similarly, when we use 2019 instead of 2020 as the reference year of the event studies, the earnings losses of directly affected workers are of the same size, between about EUR 700 and 900 per year after the flood (Appendix Figure A13).

Earlier floods Appendix Tables A15 and A16 show the same checks for the floods of 2013 and 2002. The results are equally stable. Across all specifications, directly affected workers are 0.8 to 1.3 percentage points less likely to be employed after the 2013 flood, and indirectly affected workers gain between EUR 368 and 398 per year after the 2002 flood.

Spatial regression discontinuity The matched difference-in-differences design compares workers in affected municipalities with workers in other municipalities. As an alternative that does not rely on control municipalities or matching, we compare treated workers who live just inside the border of the flooded area with treated workers who live just outside it, within the same municipalities (Appendix Figure A11 and Appendix Table A24). The change in employment between the years before and after the flood drops at the border by 1.9 to 2.7 percentage points, and the change in earnings by about EUR 1,000, depending on the bandwidth (250 to 1,000 meters). Pre-determined characteristics, such as age, gender and earnings before the flood, do not jump at the border. Estimated year by year, the jumps before the flood are small and jointly insignificant (Appendix Figure A15 and Appendix Table A25). For workplaces, we find no discontinuity, in line with the absence of losses for workers whose workplace only was flooded.

Selection into employment Wages are observed only for employed workers, so that the wage effects could reflect changes in who is employed. Appendix Figure A12 therefore repeats the event

studies for matched pairs in which both workers are employed in every year. Wages of directly affected workers fall by about one percent in the year of the flood and the following year and recover afterwards, and wages of indirectly affected workers do not change, similar to the baseline results.

Definition of exposure Appendix Table A19 compares our estimates with those from a definition of exposure at the level of the municipality, which pools directly and indirectly affected workers. The pooled estimate is close to the effect for indirectly affected workers and misses about three quarters of the earnings loss of directly affected workers.

Channels of non-employment The decomposition of the employment effect into channels assigns workers who meet the conditions of several channels to the first one in a fixed order. Appendix Table A12 uses an alternative order in which sick leave comes before establishment closures and mass layoffs. The share of mass layoffs in the employment loss of directly affected workers then falls from 40 to 31% and that of sick leave rises from 12 to 22%, so that labor demand and labor supply channels are of similar size.

Balance Before the flood, treated workers and their matched controls are close in demographics and wage histories, with small differences in tenure and establishment size (Appendix Tables A2, A5 and A6 for 2021, 2013 and 2002). Appendix Tables A3 and A4 compare their industries and occupations in 2021. Appendix Tables A27 and A28 compare affected and matched control municipalities.

Comparison of floods We compare the 2021 flood with the earlier floods with two methods: reweighting (Figure 4) and a regression-based decomposition with a double-selection lasso (Table 4). After reweighting, the treated workers of 2021 closely resemble those of 2013 in all characteristics used in the reweighting. The match with 2002 is close for age and regional characteristics but less close for full-time employment and education (Appendix Table A7). Appendix Figures A9 and A10 and Appendix Tables A17 and A18 report the results of both methods for earnings and wages.

F Appendix tables

Table A1: The three floods: damages, insurance and aid

	2002	2013	2021
River type / warning time	Large river / days	Large river / days	Small streams / hours
Damages, official estimate (EUR bn)[a]	11.6	6.7	33
Private households' share of damages[b]	24%	22%	RLP 50–55%, NRW 24%
Insured losses (EUR bn)[c]	1.9	1.8	8.6
Residential buildings with flood insurance (Germany)[c]	ca. 4%	–	ca. 46%
Emergency aid, program volume (EUR bn; share of damages)[d]	ca. 1.5 (13%)	ca. 0.9 (14%)	ca. 0.8 (2%)
Reconstruction fund, committed (EUR bn; federal / states)[e]	7.1 (3.5 / 3.6)	8 (4 / 4)	30 (16 / 14)
Fund paid out about 3 years after the flood (EUR bn; share of damages)[f]	–	2.2 (33%)	3.75 (11%)
Share of the damage the aid could cover[g]	up to 80%	up to 80%	up to 80% (hardship: 100%)
Average (max) share of municipal area flooded	0.063 (0.417)	0.092 (0.990)	0.020 (0.154)

Notes: Share of municipal area flooded: municipalities with a non-zero flooded area in the flood-extent maps. Damages, insurance and aid: compiled from laws, parliamentary papers and official reports; nominal values. [a]2002: final figure (BMI, 2022); the early federal estimate was 9.1 bn (BMI, 2013, citing DKKV, 2003). 2013: reports of the states (BT-Drs. 17/14743; BMI, 2013); 8.2 bn including federal infrastructure and insurers (BT-Drs. 18/9354). 2021: Munich Re, cited in BMI (2022); 29.2 bn reported for the EU Solidarity Fund. [b]2002: Pfurtscheller and Thieken (2013); 2013 and 2021: BMI (2022), for 2021 by state (RLP: Rhineland-Palatinate). [c]Insured losses: GDV (2025). Insurance coverage: DKKV (2003) and DKKV (2022). In 2002, about 3 million households in eastern Germany still held GDR household insurance contracts, which covered floods; half of the flood-damaged households in Saxony and Saxony-Anhalt were insured (household survey). [d]Federal and state emergency programs for households, firms, agriculture and municipalities (BMI, 2002; BT-Drs. 17/14743; for 2021 a federal share of up to 0.4 bn, half of the state programs, BT-Drs. 19/32497); approximate sums. [e]Committed when the fund was set up, before the damage was assessed; this is why the 2013 fund exceeds the damage estimate. Of the 2013 fund, 3.2 bn of the states' share and 1 bn for federal infrastructure were later returned (BR-Drs. 222/14; BT-Drs. 18/2124). In 2002, there were also 1.2 bn from EU funds and up to 1 bn from the transport budget (BT-Drs. 14/9934). [f]2013: paid out by 1 July 2016 (BT-Drs. 18/9354); 2021: paid out by 30 April 2024 (BT-Drs. 20/14000), 0.5 bn one year after the flood (DKKV, 2022). For 2002, only committed funds are reported (6.5 bn by the end of 2005; BT-Drs. 16/2704). [g]After deducting insurance payments and emergency aid (AufbauhfV 2003; AufbhV 2014; AufbhV 2021). In 2021, flood insurance was not a condition for aid (BT-Drs. 19/32497).

Table A2: Balance of matched workers, 2021

	Indirectly affected			Directly affected		
	Control	Treated	Diff. (SE)	Control	Treated	Diff. (SE)
Panel A: Demographics						
Female	0.46	0.46	0.00 (0.00)	0.50	0.50	0.00 (.)
Age	46.7	46.9	0.2 (0.1)	47.0	47.3	0.3 (0.2)
Tenure (years)	10.4	10.4	-0.0 (0.2)	9.7	10.5	0.8 (0.1)
Log daily wage	4.60	4.60	-0.00 (0.00)	4.45	4.44	-0.01 (0.00)
Full-time	0.70	0.72	0.02 (0.01)	0.63	0.67	0.04 (0.01)
Vocational training	0.75	0.75	-0.00 (0.01)	0.82	0.79	-0.02 (0.01)
University degree	0.19	0.19	-0.01 (0.01)	0.13	0.14	0.01 (0.01)
Panel B: Firm type (establishment in the year before the flood)						
Log number of employees	4.72	4.59	-0.13 (0.04)	4.10	4.07	-0.03 (0.05)
Fewer than 10 employees	0.11	0.13	0.01 (0.01)	0.15	0.15	0.00 (0.01)
10–49 employees	0.23	0.23	0.00 (0.00)	0.31	0.31	-0.00 (0.03)
50–249 employees	0.32	0.29	-0.03 (0.01)	0.36	0.30	-0.06 (0.02)
250 or more employees	0.34	0.35	0.01 (0.01)	0.19	0.24	0.06 (0.03)
Full-time share of employees	0.61	0.64	0.03 (0.02)	0.56	0.55	-0.01 (0.01)
Log median daily wage, full-time employees	4.79	4.77	-0.02 (0.01)	4.68	4.65	-0.03 (0.01)
AKM establishment effect	0.03	0.04	0.01 (0.00)	-0.01	-0.02	-0.01 (0.00)
Number of workers	55,042	55,042		5,583	5,583	

Notes: Characteristics of treated workers and their matched controls in the year before the 2021 flood (reference date 13 July 2020), separately for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Differences, with standard errors clustered at the treated municipality in parentheses. Female: share of women; gender is a matching variable, so the difference is zero by construction ("."): standard error not defined). Age in years. Tenure: years with the employer. Log daily wage of the main job. Full-time: share in full-time employment. Vocational training and university degree: shares by the highest degree (imputed education). Panel B: establishment of the employer in the year before the flood. Number of employees, size classes, full-time share of employees and median daily wage of full-time employees from the Establishment History Panel (BHP), on 30 June. AKM establishment effect: establishment fixed effect of the employer from AKM wage regressions (Lochner and Wolter, 2025). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A3: Industries of matched workers, 2021

	Indirectly affected			Directly affected		
	Control	Treated	Diff. (SE)	Control	Treated	Diff. (SE)
A Agriculture, forestry and fishing	0.002	0.003	0.000 (0.001)	0.002	0.005	0.003 (0.001)
B Mining and quarrying	0.001	0.002	0.001 (0.001)	0.002	0.003	0.001 (0.000)
C Manufacturing	0.289	0.235	-0.054 (0.011)	0.180	0.155	-0.025 (0.021)
D Electricity, gas, steam and air conditioning	0.007	0.006	-0.001 (0.002)	0.003	0.002	-0.001 (0.001)
E Water supply, sewerage, waste management	0.006	0.008	0.003 (0.003)	0.003	0.004	0.001 (0.003)
F Construction	0.050	0.049	-0.001 (0.004)	0.072	0.045	-0.027 (0.010)
G Wholesale and retail trade, repair of motor vehicles	0.149	0.181	0.032 (0.015)	0.199	0.147	-0.052 (0.022)
H Transportation and storage	0.041	0.056	0.015 (0.006)	0.054	0.050	-0.005 (0.010)
I Accommodation and food services	0.015	0.016	0.001 (0.002)	0.013	0.037	0.024 (0.011)
J Information and communication	0.032	0.023	-0.009 (0.005)	0.021	0.022	0.001 (0.001)
K Financial and insurance activities	0.036	0.041	0.004 (0.003)	0.027	0.063	0.036 (0.008)
L Real estate activities	0.004	0.005	0.001 (0.001)	0.003	0.006	0.003 (0.002)
M Professional, scientific and technical activities	0.059	0.067	0.008 (0.005)	0.061	0.051	-0.010 (0.013)
N Administrative and support services	0.036	0.039	0.004 (0.005)	0.037	0.032	-0.005 (0.004)
O Public administration and defence, social security	0.067	0.064	-0.003 (0.014)	0.070	0.083	0.013 (0.009)
P Education	0.033	0.027	-0.006 (0.006)	0.017	0.020	0.003 (0.002)
Q Human health and social work	0.144	0.152	0.007 (0.010)	0.208	0.234	0.025 (0.026)
R Arts, entertainment and recreation	0.006	0.005	-0.001 (0.001)	0.003	0.008	0.005 (0.001)
S Other service activities	0.023	0.021	-0.002 (0.003)	0.023	0.033	0.010 (0.009)
T Households as employers	0.001	0.001	0.001 (0.000)	0.002	0.001	-0.001 (0.001)
U Extraterritorial organisations	0.000	0.000	0.000 (0.000)	0.000	0.000	– (–)
Workers with a valid category	55,042	55,042		5,583	5,583	

Notes: Shares of workers by industry section of the employer (WZ 2008, sections A–U) on the reference date one year before the 2021 flood, for treated workers and their matched controls, separately for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Differences, with standard errors clustered at the treated municipality in parentheses. Shares among workers with a valid industry. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A4: Occupations of matched workers, 2021

	Indirectly affected			Directly affected		
	Control	Treated	Diff. (SE)	Control	Treated	Diff. (SE)
0 Military	0.000	0.000	-0.000 (0.000)	0.000	0.000	– (–)
1 Agriculture, forestry, animal husbandry, horticulture	0.012	0.011	-0.001 (0.002)	0.011	0.014	0.003 (0.001)
2 Raw materials, production and manufacturing	0.245	0.211	-0.034 (0.009)	0.182	0.158	-0.023 (0.007)
3 Construction, architecture, surveying, building services	0.054	0.054	-0.000 (0.004)	0.067	0.058	-0.009 (0.005)
4 Natural sciences, geography, computer science	0.034	0.043	0.009 (0.003)	0.028	0.026	-0.002 (0.003)
5 Traffic, logistics, safety and security	0.110	0.115	0.005 (0.003)	0.125	0.123	-0.002 (0.009)
6 Commercial services, trade, sales, hotels and tourism	0.114	0.123	0.008 (0.009)	0.140	0.133	-0.008 (0.005)
7 Business organisation, accounting, law and administration	0.244	0.246	0.001 (0.005)	0.233	0.250	0.018 (0.011)
8 Health, social services, teaching and education	0.169	0.180	0.011 (0.005)	0.208	0.226	0.018 (0.018)
9 Humanities, social sciences, economics, media, arts and design	0.018	0.017	-0.001 (0.005)	0.007	0.013	0.006 (0.001)
Workers with a valid category	55,042	55,042		5,583	5,583	

Notes: Shares of workers by occupational area (first digit of the KldB 2010 occupation code) on the reference date one year before the 2021 flood, for treated workers and their matched controls, separately for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Differences, with standard errors clustered at the treated municipality in parentheses. Shares among workers with a valid occupation. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A5: Balance of matched workers, 2013

	Indirectly affected			Directly affected		
	Control	Treated	Diff. (SE)	Control	Treated	Diff. (SE)
Panel A: Demographics						
Female	0.53	0.53	-0.00 (0.00)	0.49	0.49	-0.00 (0.00)
Age	45.4	45.3	-0.1 (0.0)	45.4	45.2	-0.2 (0.2)
Tenure (years)	9.7	9.5	-0.2 (0.1)	9.9	9.7	-0.2 (0.1)
Log daily wage	4.35	4.35	0.00 (0.00)	4.32	4.32	0.00 (0.00)
Full-time	0.75	0.74	-0.01 (0.00)	0.77	0.75	-0.02 (0.00)
Vocational training	0.79	0.79	0.00 (0.00)	0.81	0.79	-0.02 (0.01)
University degree	0.20	0.20	-0.00 (0.00)	0.17	0.19	0.01 (0.01)
Panel B: Firm type (establishment in the year before the flood)						
Log number of employees	4.34	4.44	0.10 (0.05)	3.78	3.95	0.17 (0.15)
Fewer than 10 employees	0.15	0.15	-0.01 (0.00)	0.21	0.19	-0.02 (0.01)
10–49 employees	0.25	0.24	-0.01 (0.01)	0.32	0.29	-0.04 (0.02)
50–249 employees	0.32	0.32	0.00 (0.01)	0.30	0.34	0.05 (0.04)
250 or more employees	0.28	0.30	0.02 (0.01)	0.17	0.18	0.01 (0.05)
Full-time share of employees	0.65	0.64	-0.01 (0.00)	0.66	0.65	-0.00 (0.01)
Log median daily wage, full-time employees	4.39	4.39	0.00 (0.00)	4.35	4.39	0.05 (0.02)
AKM establishment effect	-0.09	-0.09	0.00 (0.00)	-0.11	-0.09	0.02 (0.01)
Number of workers	201,703	201,703		7,088	7,088	

Notes: Characteristics of treated workers and their matched controls in the year before the 2013 flood (reference date 1 June 2012), separately for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Differences, with standard errors clustered at the treated municipality in parentheses. Panel A: worker characteristics. Female: share of women; gender is a matching variable, so the difference is zero by construction ("."): standard error not defined). Age in years. Tenure: years with the employer. Log daily wage of the main job. Full-time: share in full-time employment. Vocational training and university degree: shares by the highest degree (imputed education). Panel B: establishment of the employer in the year before the flood. Number of employees, size classes, full-time share of employees and median daily wage of full-time employees from the Establishment History Panel (BHP), on 30 June. AKM establishment effect: establishment fixed effect of the employer from AKM wage regressions (Lochner and Wolter, 2025). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A6: Balance of matched workers, 2002

	Indirectly affected			Directly affected		
	Control	Treated	Diff. (SE)	Control	Treated	Diff. (SE)
Panel A: Demographics						
Female	0.53	0.53	0.00 (.)	0.54	0.54	-0.00 (0.00)
Age	42.2	42.3	0.0 (0.1)	41.9	42.1	0.2 (0.1)
Tenure (years)	6.9	6.9	-0.1 (0.1)	6.9	7.0	0.0 (0.1)
Log daily wage	4.36	4.36	-0.00 (0.00)	4.26	4.26	-0.00 (0.00)
Full-time	0.86	0.86	0.01 (0.00)	0.86	0.85	-0.01 (0.01)
Vocational training	0.81	0.80	-0.01 (0.01)	0.85	0.83	-0.02 (0.01)
University degree	0.17	0.18	0.01 (0.01)	0.12	0.15	0.02 (0.01)
Panel B: Firm type (establishment in the year before the flood)						
Log number of employees	4.32	4.44	0.12 (0.03)	3.69	3.84	0.16 (0.06)
Fewer than 10 employees	0.15	0.14	-0.01 (0.00)	0.21	0.19	-0.02 (0.01)
10–49 employees	0.26	0.25	-0.00 (0.00)	0.34	0.29	-0.05 (0.02)
50–249 employees	0.31	0.32	0.01 (0.01)	0.30	0.37	0.07 (0.02)
250 or more employees	0.28	0.29	0.01 (0.01)	0.15	0.15	-0.00 (0.02)
Full-time share of employees	0.74	0.74	0.00 (0.00)	0.74	0.74	-0.01 (0.01)
Log median daily wage, full-time employees	4.17	4.16	-0.01 (0.00)	4.07	4.06	-0.01 (0.00)
AKM establishment effect	-0.12	-0.14	-0.01 (0.00)	-0.17	-0.18	-0.01 (0.01)
Number of workers	236,184	236,184		23,571	23,571	

Notes: Characteristics of treated workers and their matched controls in the year before the 2002 flood (reference date 5 August 2001), separately for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Differences, with standard errors clustered at the treated municipality in parentheses. Panel A: worker characteristics. Female: share of women; gender is a matching variable, so the difference is zero by construction ("."): standard error not defined). Age in years. Tenure: years with the employer. Log daily wage of the main job. Full-time: share in full-time employment. Vocational training and university degree: shares by the highest degree (imputed education). Panel B: establishment of the employer in the year before the flood. Number of employees, size classes, full-time share of employees and median daily wage of full-time employees from the Establishment History Panel (BHP), on 30 June. AKM establishment effect: establishment fixed effect of the employer from AKM wage regressions (Lochner and Wolter, 2025). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A7: Balance after reweighting: treated workers of 2021, reweighted to the composition of 2013 and 2002

	2021	Reweighted to 2013		Reweighted to 2002	
	unweighted	2021	2013 (West)	2021	2002
Panel A: Demographics					
Female	0.467	0.455	0.460	0.503	0.532
Age	46.9	44.8	44.3	43.0	42.2
Education: Missing	0.023	0.003	0.003	0.024	0.007
Education: Secondary school without Abitur, no vocational training	0.057	0.032	0.032	0.038	0.016
Education: Secondary school without Abitur, vocational training	0.531	0.717	0.733	0.638	0.749
Education: Abitur, no vocational training	0.011	0.003	0.003	0.005	0.001
Education: Abitur, vocational training	0.201	0.092	0.083	0.111	0.051
Education: University of applied sciences degree	0.028	0.027	0.025	0.041	0.068
Education: University degree	0.150	0.126	0.120	0.142	0.107
Panel B: Wages, employment					
Log daily wage	4.583	4.466	4.476	4.430	4.354
Tenure with the employer	10.4	10.3	10.5	6.7	6.9
Tenure in the occupation	12.1	11.1	10.8	8.0	8.2
Days unemployed	240.4	266.3	267.5	183.0	158.7
Days worked	364.7	364.9	364.9	364.6	364.2
Full-time	0.712	0.722	0.732	0.755	0.863
Panel C: Regional characteristics					
County unemployment rate	6.538	4.902	4.802	6.287	6.056
High flood-risk share, residence municipality	0.039	0.024	0.024	0.040	0.054
Outside options (standardized)	-0.017	-0.011	-0.006	-0.019	0.077

Notes: Means of the reweighting covariates for the treated workers of the 2021 flood, unweighted and reweighted, next to the treated workers of the 2013 flood (West Germany only) and of the 2002 flood. Reweighting with propensity-score odds weights (DiNardo et al., 1996): $\hat{p}/(1-\hat{p})$, where $\hat{p}$ is the predicted probability of belonging to the earlier flood from a probit on the covariates shown; workers with $\hat{p} > 0.95$ are excluded. Means over non-missing values. Education: shares of the categories of the imputed education variable; workers with missing education form their own category. Days unemployed and days worked refer to the year before the flood. If the reweighting succeeds, the reweighted 2021 columns are close to those of the earlier flood. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A8: Treated workers and matched controls by flood and exposure type

	2002	2013	2021
Indirectly affected	236,184 / 236,184	201,703 / 201,703	55,042 / 55,042
Directly affected – workplace only	10,136 / 10,136	3,817 / 3,817	2,357 / 2,357
Directly affected – home only	6,802 / 6,802	1,714 / 1,714	2,015 / 2,015
Directly affected – both	3,137 / 3,137	357 / 357	1,207 / 1,207
Share of directly affected with damage information	–	–	97.9%

Notes: Treated workers / matched controls by flood and exposure type, as defined in equation (4); the exposure type of the treated worker applies to the matched pair. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Sample: workers employed on the reference date and in the two preceding years, with at least three years of tenure with the employer and in the occupation, and without a change of residence in the three preceding years. Last row: share of directly affected treated workers whose flooded residence or workplace lies inside an area assessed by Copernicus. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps, Copernicus EMS damage grading (EMSR517).

Table A9: Damage sample, 2021

	Workplace flooded		Residence flooded		All
	Workers	Municipalities	Workers	Municipalities	Share of workers
No damage recorded (assessed area)	1,650	15	677	11	41.7%
Possibly damaged	654	12	936	11	28.5%
Damaged	439	11	1,094	12	27.5%
Destroyed	0	0	15	5	0.3%
Not assessed (status unknown)	113	3	5	1	2.1%
All directly affected	2,856	21	2,727	16	100.0%

Notes: Directly affected treated workers of the 2021 flood by the Copernicus damage grade of the flooded place: the workplace for workplace-matched pairs, the residence for residence-matched pairs. A place receives the grade of the nearest graded building within 10 meters; places inside an assessed area without such a building are "no damage recorded"; places outside the assessed areas have an unknown damage status and are not used in the damage analysis. Municipalities: treated municipalities with at least one such worker. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps, Copernicus EMS damage grading (EMSR517).

Table A10: Average post-flood effects by exposure type

		Directly affected		
	Indirectly affected	Workplace only	Home only	Both
Panel A: 2021 flood				
Earnings (EUR)	-150.0 (146.9)	139.8 (318.3)	-1769.0 (371.3)	-1092.5 (153.2)
Employment	-0.006 (0.002)	0.008 (0.007)	-0.034 (0.010)	-0.040 (0.007)
Log daily wage	0.005 (0.004)	-0.010 (0.011)	-0.005 (0.006)	-0.011 (0.015)
Treated workers	55,042	2,357	2,015	1,207
Panel B: 2013 flood				
Earnings (EUR)	93.5 (113.9)	-173.8 (256.3)	-13.6 (395.1)	-1881.1 (567.4)
Employment	0.001 (0.001)	-0.016 (0.007)	-0.005 (0.007)	-0.056 (0.017)
Log daily wage	0.004 (0.003)	0.004 (0.005)	-0.009 (0.009)	-0.018 (0.025)
Treated workers	201,703	3,817	1,714	357
Panel C: 2002 flood				
Earnings (EUR)	383.3 (64.7)	355.3 (152.4)	446.0 (167.2)	-107.6 (208.5)
Employment	0.011 (0.001)	0.009 (0.003)	0.008 (0.005)	-0.001 (0.007)
Log daily wage	0.002 (0.002)	0.005 (0.005)	0.001 (0.004)	-0.008 (0.009)
Treated workers	236,184	10,136	6,802	3,137

Notes: Average post-flood effects by exposure type: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately on the matched pairs of each exposure type in equation (4); event years −3 to +3 for 2021 and −3 to +5 for 2002 and 2013, without the flood year. The estimates correspond to τ_0, τ_W, τ_H and τ_B in equation (2). Standard errors, clustered at the treated municipality, in parentheses. Exposure types as in equation (4): workplace only, home only, or both inside the flooded area; the exposure type of the treated worker applies to the matched pair. Indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Types with fewer than 30 treated workers or 8 treated municipalities are not estimated (–). Yearly earnings: earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job. Employment: employed on the reference date in each year, the same calendar day as the day before the flood; by construction of the sample, all workers are employed before the flood. Log daily wage: daily wage of the main job, observed for employed workers only. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A11: Channels of non-employment by exposure type, 2021

			Directly affected					
	Indirect		Workplace only		Home only		Both	
	Effect (pp)	Share (%)	Effect (pp)	Share (%)	Effect (pp)	Share (%)	Effect (pp)	Share (%)
Employment effect	-0.38	100	-0.72	100	-1.74	100	-4.06	100
	(0.10)		(0.98)		(1.19)		(0.76)	
Mass layoff	0.11	30.1	0.89	123.5	0.15	8.6	1.33	32.7
	(0.04)		(0.50)		(0.06)		(0.20)	
Unemployment benefits	0.06	14.8	0.04	5.9	0.25	14.3	0.99	24.5
	(0.03)		(0.07)		(0.25)		(0.14)	
Other, still in the data	0.16	42.6	-0.00	-0.0	0.35	20.0	0.83	20.4
	(0.10)		(0.33)		(0.27)		(0.35)	
Sick leave	0.06	15.3	0.00	0.0	0.40	22.9	0.33	8.2
	(0.03)		(0.18)		(0.48)		(0.53)	
Retirement	0.00	0.5	-0.08	-11.8	0.40	22.9	0.33	8.2
	(0.04)		(0.13)		(0.56)		(0.21)	
Establishment closure	0.00	0.5	0.17	23.5	0.00	0.0	0.08	2.0
	(0.01)		(0.16)				(0.10)	
Left the data	-0.01	-3.8	-0.30	-41.2	0.20	11.4	0.17	4.1
	(0.03)		(0.32)		(0.15)		(0.21)	

Notes: Decomposition of the employment effect in year +1 (reference date 13 July 2022) into mutually exclusive channels of non-employment, estimated separately for indirectly affected workers and for the three types of directly affected workers. Exposure types as in equation (4): workplace only, home only, or both inside the flooded area; the exposure type of the treated worker applies to the matched pair. Each non-employed worker is assigned to the first applicable channel in the order establishment closure, mass layoff, sick leave, retirement. Establishment closure / mass layoff: the worker leaves an establishment whose employment falls by at least 90% / 30% between the reference dates of 2021 and 2022, defined from worker flows in the Establishment History Panel, and is not employed in 2022. Sick leave: the employment spell ends with a sickness-related reason code; after six weeks of sickness, the spell subject to social security contributions is interrupted while the employment relationship continues. Retirement: aged 62 or older in 2021 and no record in the data in 2022–2024. The remaining non-employed workers are split into "left the data" (no record in the IEB in that year: self-employment, civil service, moving abroad, death, early or disability pension), "unemployment benefits" (at least one day of unemployment benefit I in the calendar year) and "other, still in the data" (for example, recipients of basic income support only). Workers on short-time work remain employed. Each channel effect is the coefficient for year +1 of equation (5) with the channel indicator as outcome. Employment and the channel indicators add up to one for every worker, so that the channel effects add up to minus the employment effect; shares in percent of the employment effect, which can be negative. Effects in percentage points, standard errors clustered at the treated municipality in parentheses. Shares are imprecise where the employment effect is close to zero (workplace only). Rows in the order of Table 3. Treated workers: 55,042 indirectly affected; 2,357 workplace only; 2,015 home only; 1,207 both. *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A12: Channels of non-employment with an alternative priority order, 2021

	Indirectly affected		Directly affected	
	Effect (pp)	Share (%)	Effect (pp)	Share (%)
Employment effect	-0.38 (0.10)	100	-1.79 (0.83)	100
Establishment closure	-0.00 (0.01)	-0.0	0.07 (0.07)	4.0
Mass layoff	0.09 (0.04)	24.9	0.56 (0.14)	31.0
Sick leave	0.08 (0.03)	21.1	0.39 (0.39)	22.0
Retirement	0.00 (0.04)	0.5	0.16 (0.24)	9.0
Left the data	-0.01 (0.03)	-3.8	-0.02 (0.13)	-1.0
Unemployment benefits	0.06 (0.03)	14.8	0.32 (0.13)	18.0
Other, still in the data	0.16 (0.10)	42.6	0.30 (0.20)	17.0

Notes: Decomposition of the employment effect in year +1 (reference date 13 July 2022) into mutually exclusive channels of non-employment, as in Table 3, Panel A, but with an alternative priority order: each non-employed worker is assigned to the first applicable channel in the order sick leave, establishment closure, mass layoff, retirement. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Establishment closure / mass layoff: the worker leaves an establishment whose employment falls by at least 90% / 30% between the reference dates of 2021 and 2022, defined from worker flows in the Establishment History Panel, and is not employed in 2022. Sick leave: the employment spell ends with a sickness-related reason code; after six weeks of sickness, the spell subject to social security contributions is interrupted while the employment relationship continues. Retirement: aged 62 or older in 2021 and no record in the data in 2022–2024. The remaining non-employed workers are split into "left the data" (no record in the IEB in that year: self-employment, civil service, moving abroad, death, early or disability pension), "unemployment benefits" (at least one day of unemployment benefit I in the calendar year) and "other, still in the data" (for example, recipients of basic income support only). Workers on short-time work remain employed. Each channel effect is the coefficient for year +1 of equation (5) with the channel indicator as outcome. Employment and the channel indicators add up to one for every worker, so that the channel effects add up to minus the employment effect; shares in percent of the employment effect, which can be negative. Effects in percentage points, standard errors clustered at the treated municipality in parentheses. *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A13: Heterogeneity of the 2021 effects by worker and job characteristics

	Employment		Earnings (EUR)		Log wage	
	Indirect	Direct	Indirect	Direct	Indirect	Direct
Age						
20–29	-0.011 (0.004)	-0.024 (0.007)	1318 (152)	986 (511)	0.041 (0.007)	0.044 (0.013)
30–39	0.007 (0.004)	0.023 (0.008)	1164 (178)	1903 (310)	0.026 (0.006)	0.031 (0.005)
40–49	0.033 (0.003)	0.036 (0.007)	1739 (229)	1714 (313)	0.021 (0.005)	0.024 (0.013)
50+	-0.033 (0.004)	-0.057 (0.006)	-1991 (238)	-3233 (192)	-0.019 (0.005)	-0.050 (0.009)
Gender						
Men	-0.007 (0.003)	-0.018 (0.006)	-306 (133)	-831 (208)	0.001 (0.003)	-0.004 (0.006)
Women	-0.006 (0.003)	-0.018 (0.007)	-57 (200)	-815 (214)	0.008 (0.005)	-0.015 (0.007)
Education						
No vocational training	-0.023 (0.005)	-0.009 (0.017)	-420 (338)	306 (538)	0.010 (0.009)	-0.002 (0.011)
Vocational training	-0.005 (0.001)	-0.017 (0.006)	-239 (118)	-867 (140)	-0.001 (0.004)	-0.014 (0.006)
University degree	-0.007 (0.004)	-0.026 (0.006)	-15 (309)	-1331 (591)	0.019 (0.004)	0.001 (0.014)
Tenure at the baseline establishment						
3–5 years	0.007 (0.001)	-0.002 (0.007)	900 (156)	306 (205)	0.022 (0.006)	-0.002 (0.008)
5–10 years	-0.006 (0.002)	-0.018 (0.012)	27 (136)	-414 (325)	0.009 (0.004)	0.011 (0.007)
10 years or more	-0.017 (0.003)	-0.029 (0.005)	-1178 (177)	-1951 (193)	-0.013 (0.004)	-0.031 (0.010)
Industry of the baseline establishment						
Construction	-0.004 (0.008)	0.000 (0.015)	-170 (249)	557 (746)	0.005 (0.008)	-0.002 (0.023)
Hospitality	-0.017 (0.012)	0.003 (0.012)	-131 (258)	338 (252)	0.012 (0.014)	0.000 (0.005)
Public admin., education, health	-0.011 (0.002)	-0.031 (0.010)	-357 (219)	-1870 (322)	0.008 (0.007)	-0.030 (0.009)
Manufacturing, mining, energy, water	-0.009 (0.004)	-0.008 (0.005)	-614 (211)	-895 (275)	-0.001 (0.004)	-0.009 (0.008)
Trade	-0.007 (0.001)	-0.023 (0.005)	-120 (143)	-601 (216)	0.000 (0.004)	-0.014 (0.015)
Business and financial services	0.006 (0.006)	0.001 (0.009)	593 (377)	424 (545)	0.014 (0.003)	0.024 (0.014)
Other (agriculture, transport, other services)	-0.011 (0.004)	-0.030 (0.017)	-252 (112)	-725 (521)	-0.001 (0.007)	-0.002 (0.018)

Notes: Average post-flood effect by category, 2021 flood. The individual effect of a matched pair, equation (6), is the change in the treated worker's mean outcome between the years before (−4 to −1) and after (+1 to +3) the flood minus the same change for the matched control; the windows are the same for all floods. The category effects are the coefficients on category indicators in the regression of the individual effects, equation (7), with state fixed effects; standard errors clustered at the treated municipality in parentheses. Categories by the characteristics of the treated worker in year −1, which apply to the matched pair. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Tenure: with the baseline employer (the sample requires at least three years). Industry: of the baseline establishment. Employment: share of years employed on the reference date; earnings in 2015 prices; log daily wage of the main job, employed workers only. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A14: Robustness of the average post-flood effects: 2021 flood

	Earnings (EUR)		Employment		
	Indirect	Direct	Indirect	Direct	Treated (ind./dir.)
Baseline (Table 2)	-150.0 (146.9)	-816.8 (267.6)	-0.006 (0.002)	-0.017 (0.007)	55,042 / 5,583
At least 20 directly affected workers per municipality (matched sample)	-95.5 (159.5)	-866.7 (297.2)	-0.006 (0.002)	-0.019 (0.008)	44,244 / 5,442
At least 50 directly affected workers per municipality (matched sample)	-9.1 (145.4)	-867.4 (320.7)	-0.005 (0.002)	-0.019 (0.008)	40,610 / 5,236
Without high ex-ante flood risk (top decile)	-181.5 (135.5)	-851.8 (262.7)	-0.007 (0.002)	-0.018 (0.007)	53,824 / 5,487
Without big cities (230,000+ employees)	-175.0 (116.5)	-745.2 (234.5)	-0.007 (0.001)	-0.017 (0.006)	51,314 / 5,358
Controls outside the treated worker's state	-155.5 (157.0)	-882.2 (285.3)	-0.006 (0.002)	-0.018 (0.007)	51,914 / 5,303
Individual and year fixed effects only	-150.0 (146.9)	-816.8 (267.6)	-0.006 (0.002)	-0.017 (0.007)	55,042 / 5,583
Standard errors clustered by county	-150.0 (202.7)	-816.8 (266.1)	-0.006 (0.002)	-0.017 (0.006)	55,042 / 5,583
Without 2020 (COVID) in the pre-period	-91.5 (153.8)	-826.2 (258.9)	-0.006 (0.002)	-0.017 (0.007)	55,042 / 5,583

Notes: Each row repeats the estimates of Table 2 for the 2021 flood with one change. Effects: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +3 for the 2021 flood and −3 to +5 for the floods of 2002 and 2013, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. At least 20 / 50 directly affected workers: only treated municipalities with at least 20 / 50 directly affected treated workers of the same exposure type (workplace or residence) in the year before the flood; the baseline requires at least 10. Without high ex-ante flood risk: excludes pairs whose treated worker works in a municipality in the top decile of the share of area at high flood risk. Without big cities: excludes workplace municipalities with 230,000 or more employees. Controls outside the state: only pairs whose control worker lives in another federal state than the treated municipality. Individual and year fixed effects only: instead of matched-pair × year fixed effects. Standard errors clustered by county: county of the treated municipality. All restrictions apply to whole matched pairs, based on the treated worker. Treated: indirectly / directly affected treated workers in the estimation sample. Without 2020: the COVID year 2020 is excluded from the pre-flood period. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A15: Robustness of the average post-flood effects: 2013 flood

	Earnings (EUR)		Employment		
	Indirect	Direct	Indirect	Direct	Treated (ind./dir.)
Baseline (Table 2)	93.5 (113.9)	135.9 (305.6)	0.001 (0.001)	-0.011 (0.004)	201,703 / 7,088
At least 20 directly affected workers per municipality (matched sample)	96.0 (128.9)	189.8 (323.9)	0.001 (0.001)	-0.010 (0.005)	177,274 / 6,644
At least 50 directly affected workers per municipality (matched sample)	64.3 (179.4)	190.1 (357.9)	0.000 (0.002)	-0.011 (0.005)	129,693 / 5,856
Without high ex-ante flood risk (top decile)	96.3 (115.1)	70.3 (313.4)	0.001 (0.001)	-0.013 (0.005)	193,589 / 6,787
Without big cities (230,000+ employees)	96.8 (114.3)	138.6 (311.8)	0.001 (0.001)	-0.011 (0.005)	197,243 / 6,906
Controls outside the treated worker's state	209.1 (65.2)	262.5 (558.8)	0.003 (0.001)	-0.008 (0.006)	150,928 / 3,761
Individual and year fixed effects only	93.5 (113.9)	135.9 (305.6)	0.001 (0.001)	-0.011 (0.004)	201,703 / 7,088

Notes: Each row repeats the estimates for the 2013 flood with one change; event years −3 to +5. Effects: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +3 for the 2021 flood and −3 to +5 for the floods of 2002 and 2013, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. At least 20 / 50 directly affected workers: only treated municipalities with at least 20 / 50 directly affected treated workers of the same exposure type (workplace or residence) in the year before the flood; the baseline requires at least 10. Without high ex-ante flood risk: excludes pairs whose treated worker works in a municipality in the top decile of the share of area at high flood risk. Without big cities: excludes workplace municipalities with 230,000 or more employees. Controls outside the state: only pairs whose control worker lives in another federal state than the treated municipality. Individual and year fixed effects only: instead of matched-pair × year fixed effects. Standard errors clustered by county: county of the treated municipality. All restrictions apply to whole matched pairs, based on the treated worker. Treated: indirectly / directly affected treated workers in the estimation sample. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A16: Robustness of the average post-flood effects: 2002 flood

	Earnings (EUR)		Employment		
	Indirect	Direct	Indirect	Direct	Treated (ind./dir.)
Baseline (Table 2)	383.3 (64.7)	214.3 (188.1)	0.011 (0.001)	0.006 (0.003)	236,184 / 23,571
At least 20 directly affected workers per municipality (matched sample)	389.1 (72.9)	215.2 (196.6)	0.012 (0.001)	0.006 (0.004)	204,636 / 22,787
At least 50 directly affected workers per municipality (matched sample)	368.2 (75.0)	203.5 (207.9)	0.011 (0.001)	0.007 (0.004)	181,188 / 21,470
Without high ex-ante flood risk (top decile)	391.7 (65.9)	220.7 (190.2)	0.011 (0.001)	0.006 (0.003)	231,402 / 23,199
Without big cities (230,000+ employees)	386.8 (63.5)	208.2 (187.1)	0.011 (0.001)	0.006 (0.003)	235,538 / 23,521
Controls outside the treated worker's state	398.4 (69.5)	166.0 (226.3)	0.012 (0.001)	0.005 (0.004)	217,826 / 19,016
Individual and year fixed effects only	383.3 (64.7)	214.3 (188.1)	0.011 (0.001)	0.006 (0.003)	236,184 / 23,571
Standard errors clustered by county	383.3 (67.0)	214.3 (195.9)	0.011 (0.002)	0.006 (0.004)	236,184 / 23,571

Notes: Each row repeats the estimates for the 2002 flood with one change; event years −3 to +5. Effects: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +3 for the 2021 flood and −3 to +5 for the floods of 2002 and 2013, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. At least 20 / 50 directly affected workers: only treated municipalities with at least 20 / 50 directly affected treated workers of the same exposure type (workplace or residence) in the year before the flood; the baseline requires at least 10. Without high ex-ante flood risk: excludes pairs whose treated worker works in a municipality in the top decile of the share of area at high flood risk. Without big cities: excludes workplace municipalities with 230,000 or more employees. Controls outside the state: only pairs whose control worker lives in another federal state than the treated municipality. Individual and year fixed effects only: instead of matched-pair × year fixed effects. Standard errors clustered by county: county of the treated municipality. All restrictions apply to whole matched pairs, based on the treated worker. Treated: indirectly / directly affected treated workers in the estimation sample. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A17: Contributions of worker and regional characteristics to the earnings gap between 2021 and earlier floods

	2021 vs. 2013		2021 vs. 2002	
	Indirect	Direct	Indirect	Direct
Raw gap (EUR)	-43.02	-1860.42	-591.71	-1266.64
Adjusted gap, lasso (EUR)	211.16 (165.51)	-721.33 (398.31)	212.82 (96.17)	275.97 (295.35)
Contribution of differences in:				
Age	-498.90	-736.51	-670.37	-977.52
Log daily wage	-49.55	-11.03	76.24	5.66
Tenure	-15.89	-42.26	-258.44	-513.14
Days in unemployment	2.27	3.01	-24.98	-76.82
Days worked	4.47	-1.55	-0.12	-4.93
Female	-0.13	7.85	1.19	12.67
Full-time	6.58	49.41	89.20	136.74
Education	37.46	-5.93	111.72	159.00
County unemployment rate	-224.87	-425.85	4.53	-107.76
High flood-risk share	12.53	27.57	4.59	-29.61
Outside options	-7.69	-11.15	-40.19	-5.54
Municipality type	599.49	-134.56	-7.10	-5.82
Sum of contributions	-134.23	-1281.00	-713.63	-1407.21

Notes: Gap: average individual effect of workers affected in 2021 minus that of workers affected in the earlier flood, separately for indirectly and directly affected workers. The individual effect of a matched pair, equation (6), is the change in the treated worker's mean outcome between the years before (−4 to −1) and after (+1 to +3) the flood minus the same change for the matched control; the windows are the same for all floods. Contribution of characteristic k: $\hat{\gamma}_k(\bar{x}_k^{2021} - \bar{x}_k^{\text{earlier}})$, where $\hat{\gamma}_k$ is the coefficient from one regression of the individual effects of both floods on all characteristics, equation (7); contributions are summed within the groups shown and need not add up to the raw gap. Adjusted gap: gap conditional on all characteristics, estimated with the double-selection lasso of Belloni et al. (2014); standard errors in parentheses. Tenure: with the employer and in the occupation. Education: indicators for the categories of the imputed education variable. Municipality type: indicators for the BBSR town and municipality type of the residence and the workplace municipality. Outside options: transition-weighted employment in the other occupations of the worker's commuting zone (standardized). Missing characteristics are set to zero and flagged; the flags enter the regressions and the sum of contributions, but are not shown (contributions below 0.01 percentage points). Workers of 2021 with a propensity score above 0.95 in the reweighting to the earlier flood are excluded. The comparison with 2013 uses workers in West Germany only. Outcome: yearly earnings, EUR in 2015 prices, zero for workers without a job. Log daily wage: Appendix Table A18. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A18: Contributions of worker and regional characteristics to the wage gap between 2021 and earlier floods

	2021 vs. 2013		2021 vs. 2002	
	Indirect	Direct	Indirect	Direct
Raw gap (100 x log points)	0.84	-3.95	0.15	-0.71
Adjusted gap, lasso (100 x log points)	0.80 (0.40)	-3.11 (1.01)	1.28 (0.26)	1.30 (0.89)
Contribution of differences in:				
Age	-0.66	-1.23	-1.41	-2.31
Log daily wage	-0.03	0.02	0.21	0.29
Tenure	-0.06	0.01	-0.06	-0.52
Days in unemployment	0.00	-0.01	-0.03	-0.04
Days worked	0.00	-0.01	0.00	-0.00
Female	0.00	-0.04	0.04	0.05
Full-time	0.01	0.10	0.32	0.65
Education	0.16	0.07	0.32	0.46
County unemployment rate	0.07	-0.12	0.02	-0.02
High flood-risk share	0.05	0.03	0.04	0.17
Outside options	-0.01	-0.09	-0.02	-0.05
Municipality type	0.90	-0.52	-0.07	-0.17
Sum of contributions	0.45	-1.79	-0.64	-1.51

Notes: Gap: average individual effect of workers affected in 2021 minus that of workers affected in the earlier flood, separately for indirectly and directly affected workers. The individual effect of a matched pair, equation (6), is the change in the treated worker's mean outcome between the years before (−4 to −1) and after (+1 to +3) the flood minus the same change for the matched control; the windows are the same for all floods. Contribution of characteristic k: $\hat{\gamma}_k(\bar{x}_k^{2021} - \bar{x}_k^{\text{earlier}})$, where $\hat{\gamma}_k$ is the coefficient from one regression of the individual effects of both floods on all characteristics, equation (7); contributions are summed within the groups shown and need not add up to the raw gap. Adjusted gap: gap conditional on all characteristics, estimated with the double-selection lasso of Belloni et al. (2014); standard errors in parentheses. Tenure: with the employer and in the occupation. Education: indicators for the categories of the imputed education variable. Municipality type: indicators for the BBSR town and municipality type of the residence and the workplace municipality. Outside options: transition-weighted employment in the other occupations of the worker's commuting zone (standardized). Missing characteristics are set to zero and flagged; the flags enter the regressions and the sum of contributions, but are not shown (contributions below 0.01 percentage points). Workers of 2021 with a propensity score above 0.95 in the reweighting to the earlier flood are excluded. The comparison with 2013 uses workers in West Germany only. Outcome: log daily wage of the main job, in 100 × log points, employed workers only. Yearly earnings: Appendix Table A17. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A19: What a municipality-level treatment definition does

	Municipality-level	Indirect	Direct	Share direct	Coarse minus direct	Share of direct effect missed (%)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: 2021 flood						
Total yearly earnings (EUR)	-211.4 (129.7)	-150.0 (146.9)	-816.8 (267.6)	0.09	605.5	74
Employment	-0.007 (0.002)	-0.006 (0.002)	-0.017 (0.007)	0.09	0.010	57
Log daily wage	0.004 (0.003)	0.005 (0.004)	-0.008 (0.006)	0.09	0.012	144
Days worked	-2.5 (0.3)	-2.2 (0.3)	-4.9 (1.6)	0.09	2.4	49
Panel B: 2013 flood						
Total yearly earnings (EUR)	95.0 (109.2)	93.5 (113.9)	135.9 (305.6)	0.03	-40.9	–
Employment	0.001 (0.001)	0.001 (0.001)	-0.011 (0.004)	0.03	0.012	107
Log daily wage	0.004 (0.003)	0.004 (0.003)	0.003 (0.006)	0.03	0.001	–
Days worked	0.3 (0.2)	0.4 (0.2)	-0.5 (1.1)	0.03	0.9	–
Panel C: 2002 flood						
Total yearly earnings (EUR)	367.9 (66.1)	383.3 (64.7)	214.3 (188.1)	0.09	153.6	-72
Employment	0.011 (0.001)	0.011 (0.001)	0.006 (0.003)	0.09	0.005	-81
Log daily wage	0.002 (0.002)	0.002 (0.002)	-0.000 (0.006)	0.09	0.002	–
Days worked	2.3 (0.4)	2.3 (0.4)	2.2 (1.1)	0.09	0.1	-2

Notes: Average post-flood effects, 2021 flood, from the static version of equation (5) with individual and matched-pair × year fixed effects; standard errors, clustered at the treated municipality, in parentheses. Column (1), $\hat{\beta}^M$: all treated workers pooled in one regression without the direct/indirect split, as in studies that treat everyone in a flooded municipality as affected. Columns (2) and (3), $\hat{\beta}^I$ and $\hat{\beta}^D$: separate regressions for indirectly and directly affected workers. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Column (4), s: share of directly affected workers among the treated. With matched-pair × year fixed effects and one-to-one pairs, the municipality-level estimate is exactly the share-weighted average of the two group effects, $\hat{\beta}^M = s\,\hat{\beta}^D + (1-s)\,\hat{\beta}^I$, as in equation (3). Column (5) is therefore $\hat{\beta}^M - \hat{\beta}^D = (1-s)\,(\hat{\beta}^I - \hat{\beta}^D)$, the misstatement of the effect for the directly affected. Column (6): share of the direct effect missed by the municipality-level definition, $100\,(\hat{\beta}^D - \hat{\beta}^M)/\hat{\beta}^D$; values above 100 mean that $\hat{\beta}^M$ has the opposite sign of $\hat{\beta}^D$, negative values that $\hat{\beta}^M$ exceeds $\hat{\beta}^D$; "–" if $|\hat{\beta}^D|$ is smaller than its standard error. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A20: Average post-flood effects: indirectly vs. directly affected workers : days worked and mobility

	Indirectly affected		Directly affected		Direct minus indirect	
	Effect	Ctrl. mean (baseline)	Effect	Ctrl. mean (baseline)	Difference [p-value]	Treated (ind./dir.)
Panel A: 2021 flood						
Days worked	**-2.2 (0.3)**	364.7	**-4.9 (1.6)**	364.7	-2.7 (1.6) [0.107]	55,042 / 5,583
Days worked full-time	-0.8 (0.9)	253.5	**-9.4 (1.3)**	229.6	**-8.6 (1.2)** [0.000]	
Workplace county changed	0.006 (0.004)	0.000	-0.009 (0.004)	0.000	**-0.015 (0.005)** [0.005]	
Residence county changed	-0.003 (0.005)	0.000	0.002 (0.003)	0.000	0.005 (0.004) [0.280]	
Panel B: 2013 flood						
Days worked	0.4 (0.2)	365.0	-0.5 (1.1)	364.9	-0.9 (1.1) [0.408]	201,703 / 7,088
Days worked full-time	**-1.7 (0.5)**	275.2	-3.2 (2.1)	281.9	-1.4 (2.2) [0.511]	
Workplace county changed	0.001 (0.002)	0.000	0.002 (0.004)	0.000	0.001 (0.005) [0.906]	
Residence county changed	-0.002 (0.001)	0.000	-0.001 (0.002)	0.000	0.001 (0.002) [0.487]	
Panel C: 2002 flood						
Days worked	**2.3 (0.4)**	364.3	2.2 (1.1)	364.4	-0.1 (1.1) [0.957]	236,184 / 23,571
Days worked full-time	-2.9 (3.0)	313.1	3.1 (1.9)	313.6	6.1 (3.3) [0.068]	
Workplace county changed	-0.005 (0.005)	0.000	0.001 (0.004)	0.000	0.006 (0.006) [0.313]	
Residence county changed	**-0.008 (0.003)**	0.000	-0.002 (0.002)	0.000	**0.006 (0.003)** [0.016]	

Notes: Effects: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +3 for the 2021 flood and −3 to +5 for the floods of 2002 and 2013, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Days worked: days in employment subject to social security contributions in the calendar year, in all jobs and in full-time jobs; zero for workers without a job. County changed: the workplace or residence county differs from that on the reference date, the day before the flood (workers without a job have no workplace county). Control mean (baseline): mean of the matched controls in the calendar year before the flood for days worked, and on the reference date for the county changes, which equal zero there by construction. Direct minus indirect: coefficient on the interaction of treated × post-flood with direct exposure in one regression for both groups; p-value of the test of equality in brackets. Coefficients and standard errors in bold are significant at the 5% level (difference: p-value below 0.05). *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A21: Firm reallocation: average post-flood effects, 2021 flood

	Indirectly affected		Directly affected		Direct minus indirect	
	Effect	Ctrl. mean (baseline)	Effect	Ctrl. mean (baseline)	Difference [p-value]	Treated (ind./dir.)
At baseline establishment	**-0.019 (0.003)**	0.999	**-0.037 (0.013)**	0.999	-0.017 (0.013) [0.186]	55,042 / 5,583
At a different establishment	**0.013 (0.003)**	0.001	0.020 (0.011)	0.001	0.007 (0.011) [0.561]	
Moved to higher-paying establishment	**0.007 (0.002)**	0.000	**0.010 (0.003)**	0.000	0.002 (0.003) [0.465]	
Moved to lower-paying establishment	-0.001 (0.002)	0.000	0.001 (0.005)	0.000	0.003 (0.005) [0.601]	
Change in AKM establishment effect	0.000 (0.000)	0.000	**0.002 (0.001)**	-0.000	0.002 (0.001) [0.085]	
AKM establishment effect (employed)	0.000 (0.000)	0.034	**0.002 (0.001)**	-0.013	0.002 (0.001) [0.084]	
Entered construction	**0.001 (0.000)**	0.000	**0.003 (0.001)**	0.000	0.002 (0.001) [0.144]	
Entered public admin., education, health	**0.002 (0.000)**	0.000	0.002 (0.001)	0.000	-0.000 (0.001) [0.704]	
Industry changed	**0.007 (0.003)**	0.000	0.005 (0.006)	0.000	-0.002 (0.006) [0.758]	
Workplace municipality changed	**0.012 (0.006)**	0.000	0.009 (0.007)	0.000	-0.003 (0.008) [0.670]	

Notes: Average post-flood effects on reallocation outcomes for the 2021 flood: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +3, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Outcomes refer to the baseline establishment, the establishment of year −1, and are zero for workers without a job, except the AKM establishment effect (employed workers only). At baseline establishment: employed there; at a different establishment: employed elsewhere. Up / down move: employed at a different establishment whose AKM effect is higher / lower than that of the baseline establishment. AKM establishment effect: fixed effect of the current employer from AKM wage regressions estimated for 1993–2000, 2001–2008, 2009–2016 and 2017–2023 (Lochner and Wolter, 2025); levels are comparable only within a period; change: difference to the baseline establishment. Entered construction / public administration, education, health: employed in that sector and not in it in year −1. Industry / workplace municipality changed: differs from that on the reference date, the day before the flood. Control mean (baseline): mean of the matched controls on the reference date, the day before the flood; by construction, almost all workers are still at their baseline establishment and the indicators for moves and sector entry are close to zero. Direct minus indirect: coefficient on the interaction of treated × post-flood with direct exposure in one regression for both groups; p-value of the test of equality in brackets. Coefficients and standard errors in bold are significant at the 5% level (difference: p-value below 0.05). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A22: Firm reallocation: average post-flood effects, 2013 flood

	Indirectly affected		Directly affected		Direct minus indirect	
	Effect	Ctrl. mean (baseline)	Effect	Ctrl. mean (baseline)	Difference [p-value]	Treated (ind./dir.)
At baseline establishment	**0.010 (0.003)**	0.999	-0.000 (0.006)	0.999	-0.011 (0.006) [0.062]	201,703 / 7,088
At a different establishment	**-0.009 (0.002)**	0.000	-0.011 (0.006)	0.001	-0.002 (0.005) [0.693]	
Moved to higher-paying establishment	**-0.005 (0.002)**	0.000	-0.007 (0.006)	0.001	-0.001 (0.005) [0.808]	
Moved to lower-paying establishment	-0.002 (0.001)	0.000	-0.001 (0.004)	0.000	0.001 (0.004) [0.777]	
Change in AKM establishment effect	0.001 (0.001)	0.000	-0.002 (0.003)	0.000	-0.002 (0.003) [0.446]	
AKM establishment effect (employed)	0.001 (0.001)	-0.093	-0.002 (0.003)	-0.111	-0.002 (0.003) [0.446]	
Entered construction	0.000 (0.000)	0.000	0.001 (0.001)	0.000	0.001 (0.001) [0.487]	
Entered public admin., education, health	0.002 (0.001)	0.001	0.002 (0.001)	0.001	-0.000 (0.002) [0.971]	
Industry changed	0.001 (0.003)	0.000	**0.009 (0.003)**	0.000	**0.008 (0.004)** [0.020]	
Workplace municipality changed	-0.001 (0.002)	0.000	0.006 (0.005)	0.000	0.007 (0.005) [0.131]	

Notes: Average post-flood effects on reallocation outcomes for the 2013 flood: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +5, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Outcomes refer to the baseline establishment, the establishment of year −1, and are zero for workers without a job, except the AKM establishment effect (employed workers only). At baseline establishment: employed there; at a different establishment: employed elsewhere. Up / down move: employed at a different establishment whose AKM effect is higher / lower than that of the baseline establishment. AKM establishment effect: fixed effect of the current employer from AKM wage regressions estimated for 1993–2000, 2001–2008, 2009–2016 and 2017–2023 (Lochner and Wolter, 2025); levels are comparable only within a period; change: difference to the baseline establishment. Entered construction / public administration, education, health: employed in that sector and not in it in year −1. Industry / workplace municipality changed: differs from that on the reference date, the day before the flood. Control mean (baseline): mean of the matched controls on the reference date, the day before the flood; by construction, almost all workers are still at their baseline establishment and the indicators for moves and sector entry are close to zero. Direct minus indirect: coefficient on the interaction of treated × post-flood with direct exposure in one regression for both groups; p-value of the test of equality in brackets. Coefficients and standard errors in bold are significant at the 5% level (difference: p-value below 0.05). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A23: Firm reallocation: average post-flood effects, 2002 flood

	Indirectly affected		Directly affected		Direct minus indirect	
	Effect	Ctrl. mean (baseline)	Effect	Ctrl. mean (baseline)	Difference [p-value]	Treated (ind./dir.)
At baseline establishment	**0.021 (0.009)**	1.000	**0.030 (0.006)**	1.000	0.008 (0.010) [0.390]	236,184 / 23,571
At a different establishment	-0.010 (0.008)	0.000	**-0.024 (0.004)**	0.000	-0.014 (0.009) [0.115]	
Moved to higher-paying establishment	-0.003 (0.007)	0.000	**-0.011 (0.004)**	0.000	-0.007 (0.008) [0.366]	
Moved to lower-paying establishment	**-0.006 (0.002)**	0.000	**-0.010 (0.004)**	0.000	-0.004 (0.004) [0.294]	
Change in AKM establishment effect	**-0.007 (0.002)**	0.000	-0.006 (0.004)	-0.000	0.000 (0.004) [0.967]	
AKM establishment effect (employed)	**-0.007 (0.002)**	-0.123	-0.006 (0.004)	-0.172	0.000 (0.004) [0.938]	
Entered construction	-0.000 (0.000)	0.000	0.000 (0.001)	0.000	0.000 (0.001) [0.598]	
Entered public admin., education, health	**-0.001 (0.001)**	0.000	-0.001 (0.001)	0.000	0.000 (0.001) [0.601]	
Industry changed	**-0.007 (0.002)**	0.000	**-0.005 (0.002)**	0.000	0.002 (0.003) [0.460]	
Workplace municipality changed	-0.006 (0.004)	0.000	-0.001 (0.005)	0.000	0.005 (0.006) [0.468]	

Notes: Average post-flood effects on reallocation outcomes for the 2002 flood: coefficient on treated × post-flood in the static version of equation (5), with individual and matched-pair × year fixed effects, estimated separately for indirectly and directly affected workers; event years −3 to +5, without the flood year. Standard errors, clustered at the treated municipality, in parentheses. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Outcomes refer to the baseline establishment, the establishment of year −1, and are zero for workers without a job, except the AKM establishment effect (employed workers only). At baseline establishment: employed there; at a different establishment: employed elsewhere. Up / down move: employed at a different establishment whose AKM effect is higher / lower than that of the baseline establishment. AKM establishment effect: fixed effect of the current employer from AKM wage regressions estimated for 1993–2000, 2001–2008, 2009–2016 and 2017–2023 (Lochner and Wolter, 2025); levels are comparable only within a period; change: difference to the baseline establishment. Entered construction / public administration, education, health: employed in that sector and not in it in year −1. Industry / workplace municipality changed: differs from that on the reference date, the day before the flood. Control mean (baseline): mean of the matched controls on the reference date, the day before the flood; by construction, almost all workers are still at their baseline establishment and the indicators for moves and sector entry are close to zero. Direct minus indirect: coefficient on the interaction of treated × post-flood with direct exposure in one regression for both groups; p-value of the test of equality in brackets. Coefficients and standard errors in bold are significant at the 5% level (difference: p-value below 0.05). *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A24: Spatial RDD at the border of the flooded area, 2021

Panel A: Workplace

	Bandwidth 250 m	Bandwidth 500 m	Bandwidth 1000 m
Change in yearly earnings (EUR)	1610.2 (1301.2)	2018.4 (1054.2)	1372.1 (981.9)
Change in employment	-0.002 (0.012)	-0.012 (0.015)	-0.006 (0.012)
Change in log daily wage	0.010 (0.029)	0.017 (0.025)	0.009 (0.029)
Change in days worked	-1.2 (2.3)	-5.4 (3.7)	-3.9 (2.9)
Placebo: age	0.3 (1.1)	0.4 (0.8)	0.3 (0.7)
Placebo: female	0.013 (0.098)	0.141 (0.096)	0.110 (0.066)
Placebo: log daily wage, t=-1	-0.177 (0.173)	-0.300 (0.169)	-0.225 (0.108)
Placebo: yearly earnings, t=-1	-8678.8 (7660.8)	-12490.5 (7123.8)	-8724.6 (4233.1)
Workers inside / outside	2,342 / 7,896	2,356 / 14,100	2,356 / 23,117

Panel B: Residence

	Bandwidth 250 m	Bandwidth 500 m	Bandwidth 1000 m
Change in yearly earnings (EUR)	-981.3 (418.0)	-1067.1 (655.2)	-906.5 (663.0)
Change in employment	-0.019 (0.008)	-0.027 (0.008)	-0.024 (0.008)
Change in log daily wage	-0.013 (0.013)	-0.010 (0.007)	-0.012 (0.005)
Change in days worked	-5.4 (3.3)	-7.7 (2.7)	-7.7 (2.2)
Placebo: age	1.0 (0.6)	0.5 (0.6)	0.1 (0.6)
Placebo: female	0.014 (0.025)	0.000 (0.019)	0.002 (0.015)
Placebo: log daily wage, t=-1	-0.018 (0.043)	-0.009 (0.052)	-0.016 (0.046)
Placebo: yearly earnings, t=-1	-1036.8 (1599.8)	-1345.7 (2007.1)	-2033.9 (1927.4)
Workers inside / outside	1,864 / 5,740	1,993 / 10,722	2,015 / 16,149

Notes: Spatial regression discontinuity design at the border of the flooded area: treated workers of the 2021 flood within the bandwidth around the border, in the same affected municipalities; no control municipalities are used. Running variable: distance to the border in meters (positive inside the flooded area). Panel A: workplace-matched sample without workers whose residence was flooded, by the distance of the workplace; Panel B: residence-matched sample without workers whose workplace was flooded, by the distance of the residence. Outcome: individual change between the mean in the years before (-3 to -1) and after ($+1$ to $+3$) the flood. Cells: jump at the border from a local linear regression with a triangular kernel and separate slopes on each side; standard errors clustered at the treated municipality in parentheses. Placebo rows: characteristics in year -1, which should not jump. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A25: Spatial RDD at the border of the flooded area, by year: residence, 2021

Year relative to the flood	Yearly earnings (EUR)	Employment	Days worked	Log daily wage
-3	262.3 (193.4)	0.000 (0.003)	-0.4 (1.2)	0.010 (0.007)
-2	184.0 (232.0)	0.000 (0.000)	-0.2 (0.1)	0.001 (0.003)
-1 (reference)	0	0	0	0
0	-55.9 (209.1)	0.000 (0.000)	-2.3 (0.7)	-0.002 (0.003)
1	-225.2 (341.0)	-0.005 (0.009)	-5.9 (2.5)	-0.016 (0.009)
2	-1406.5 (379.5)	-0.043 (0.010)	-12.1 (3.2)	-0.002 (0.014)
3	-461.6 (819.6)	-0.002 (0.013)	-3.0 (4.3)	-0.012 (0.015)
Joint test of no pre-flood jumps (p)	0.370	0.904	0.323	0.106
Workers inside / outside	1,993 / 10,722	1,993 / 10,722	1,993 / 10,722	1,993 / 10,722

Notes: Spatial regression discontinuity design at the border of the flooded area by year: treated workers of the 2021 flood in the residence-matched sample within 500 meters of the border, without workers whose workplace was flooded; no control municipalities are used. Cells: jump at the border in the worker's change of the outcome relative to year −1, from one stacked local linear regression with a triangular kernel and separate intercepts, jumps and slopes on each side of the border for every year; standard errors clustered at the treated municipality in parentheses. Year 0 is the flood year: employment refers to the day before the flood, earnings and days worked to the whole calendar year. Joint test: all jumps before the flood are zero. Workers inside / outside: within 500 meters of the border, year −1. Graph version: Appendix Figure A15. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A26: Age profile of the 2021 effects: employment channels and moves

	Age 16–29		Age 30–49		Age 50+	
	Indirect	Direct	Indirect	Direct	Indirect	Direct
Panel A: Employment effect and channels, year +1 (pp)						
Employment effect	-1.32 (0.68)	-2.92 (2.02)	0.88 (0.33)	0.43 (0.89)	-1.40 (0.28)	-3.42 (0.76)
Establishment closure	0.02 (0.03)	0.00 (.)	-0.00 (0.01)	0.00 (.)	0.00 (0.01)	0.18 (0.16)
Mass layoff	0.02 (0.09)	0.22 (0.23)	0.09 (0.04)	0.22 (0.08)	0.15 (0.05)	1.20 (0.35)
Sick leave	0.22 (0.14)	1.12 (0.44)	0.03 (0.07)	-0.26 (0.48)	0.06 (0.09)	0.46 (0.22)
Retirement	-0.32 (0.07)	-0.22 (0.23)	-0.52 (0.06)	-0.65 (0.10)	0.53 (0.08)	0.88 (0.48)
Left the data	0.57 (0.26)	0.00 (0.74)	-0.15 (0.04)	-0.00 (0.15)	0.02 (0.06)	-0.04 (0.26)
Unemployment benefits	-0.15 (0.32)	-0.22 (0.32)	0.01 (0.05)	0.65 (0.40)	0.13 (0.06)	0.14 (0.17)
Other, still in the data	0.95 (0.21)	2.02 (1.14)	-0.34 (0.21)	-0.39 (0.22)	0.51 (0.15)	0.60 (0.24)
Panel B: Moves, average post-flood effect (pp)						
Residence county changed	0.80 (0.86)	-0.66 (1.10)	-0.25 (0.53)	0.31 (0.43)	-0.56 (0.36)	0.16 (0.27)
Residence municipality changed	1.26 (0.66)	4.49 (2.55)	-0.80 (0.21)	1.68 (0.89)	-1.12 (0.22)	2.00 (0.58)
Workplace county changed	3.18 (0.62)	0.49 (1.94)	1.29 (0.38)	-0.55 (0.70)	-0.63 (0.54)	-1.50 (0.55)

Notes: Groups by the age of the treated worker in year −1, which applies to the matched pair; 2021 flood. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Panel A: decomposition of the employment effect in year +1 into mutually exclusive channels of non-employment, estimated separately for each age group; channels and priority order as in Table 3 (establishment closure, mass layoff, sick leave, retirement; then left the data, unemployment benefits, other). Each effect is the coefficient for year +1 of equation (5). Panel B: average post-flood effect on moving, from the static version of equation (5); the indicators equal one if the residence or workplace municipality or county differs from that on the reference date, the day before the flood. Percentage points; standard errors clustered at the treated municipality in parentheses. *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Table A27: Balance of affected and matched control municipalities: municipality characteristics

	2002 flood (2001)			2013 flood (2012)			2021 flood (2020)		
	Affected	Controls	Difference	Affected	Controls	Difference	Affected	Controls	Difference
Population (1,000)	13.18	10.46	2.72**	12.38	12.76	−0.38	25.29	22.04	3.25
			(1.30)			(0.53)			(2.08)
Employees at workplace (1,000)	4.66	3.78	0.88	4.83	4.96	−0.13	10.37	11.29	−0.93
			(0.56)			(0.24)			(1.61)
Population share aged under 18	0.171	0.177	−0.005***	0.151	0.151	−0.000	0.160	0.165	−0.005*
			(0.001)			(0.002)			(0.002)
Population share aged 18–29	0.137	0.140	−0.003***	0.115	0.114	0.000	0.118	0.120	−0.002
			(0.001)			(0.001)			(0.002)
Population share aged 30–64	0.505	0.510	−0.005*	0.509	0.508	0.001	0.486	0.491	−0.004**
			(0.003)			(0.002)			(0.002)
Population share aged 65 and older	0.187	0.173	0.014***	0.226	0.228	−0.002	0.236	0.225	0.011**
			(0.004)			(0.003)			(0.005)
River length (km per km^2)	1.509	0.820	0.689***	0.848	0.754	0.094	0.472	0.493	−0.020
			(0.132)			(0.057)			(0.044)
Matched pairs (counties of affected municipalities)		302 (25)			261 (45)			265 (32)	

Notes: Municipality characteristics in the year before each flood of the affected municipalities and their matched control municipalities. Each affected municipality (non-zero flooded area) is matched to one municipality in a county without affected municipalities, exactly on East or West Germany, municipality size class, an indicator for an above-median wage and an indicator for a local economic downturn, and by Mahalanobis distance on the other characteristics; Dresden and Leipzig are matched to West German cities. Difference: mean difference within pairs, standard errors clustered by the county of the affected municipality in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. "–": exact-matching variable. *Source:* INKAR (BBSR), Federal Statistical Office, IAB establishment and employment data aggregated to municipalities and counties.

Table A28: Balance of affected and matched control municipalities: characteristics of the county

	2002 flood (2001)			2013 flood (2012)			2021 flood (2020)		
	Affected	Controls	Difference	Affected	Controls	Difference	Affected	Controls	Difference
Panel A: County location, type, labor market									
West Germany	0.013	0.020	−0.007	0.425	0.429	−0.004	1.000	1.000	–
			(0.005)			(0.004)			
County type: large city	0.013	0.017	−0.003	0.019	0.023	−0.004	0.053	0.049	0.004
			(0.003)			(0.004)			(0.004)
County type: urban county	0.242	0.053	0.189*	0.073	0.230	−0.157**	0.230	0.317	−0.087
			(0.108)			(0.075)			(0.094)
County type: rural county	0.745	0.930	−0.185*	0.908	0.747	0.161**	0.717	0.634	0.083
			(0.107)			(0.075)			(0.095)
Population density (per km^2)	184.8	120.8	64.0***	140.3	161.0	−20.7**	281.3	265.1	16.2
			(18.0)			(9.3)			(36.7)
Unemployment rate (%)	4.86	5.43	−0.56*	2.93	3.58	−0.64**	4.63	5.00	−0.36
			(0.31)			(0.27)			(0.46)
Median daily wage (EUR)	70.1	71.8	−1.7***	82.6	83.6	−0.9	102.5	106.9	−4.4***
			(0.4)			(0.7)			(1.5)
Relative economic downturn	0.013	0.013	–	0.280	0.280	–	0.879	0.879	–
Net migration rate, 5-year mean	-0.88	-1.07	0.19	-1.58	-1.81	0.22	6.13	5.19	0.94
			(1.98)			(0.64)			(0.96)
Panel B: County industry composition									
Industry share: agriculture (A)	0.034	0.038	−0.004	0.044	0.038	0.006**	0.051	0.039	0.012
			(0.003)			(0.002)			(0.010)
Industry share: manufacturing (C)	0.088	0.070	0.018***	0.081	0.081	0.000	0.064	0.066	−0.002
			(0.006)			(0.002)			(0.003)
Industry share: construction (F)	0.135	0.132	0.004*	0.118	0.114	0.005**	0.093	0.098	−0.005
			(0.002)			(0.002)			(0.005)
Industry share: trade (G)	0.192	0.193	−0.001	0.181	0.183	−0.003**	0.146	0.144	0.002
			(0.004)			(0.001)			(0.001)
Industry share: hospitality (I)	0.068	0.077	−0.010***	0.067	0.071	−0.004	0.078	0.069	0.010**
			(0.003)			(0.003)			(0.004)
Industry share: business and other services (K–N, R, S)	0.259	0.256	0.003	0.248	0.252	−0.004	0.242	0.259	−0.017***
			(0.004)			(0.004)			(0.004)
Industry share: public sector (O–Q)	0.133	0.142	−0.009***	0.125	0.128	−0.004	0.129	0.124	0.005*
			(0.003)			(0.002)			(0.003)
Matched pairs (counties of affected municipalities)	302 (25)			261 (45)			265 (32)		

Notes: Characteristics of the county of the affected municipalities and their matched control municipalities in the year before each flood. Panel A: location, county type and labor market; Panel B: industry shares (WZ 2008 sections). Each affected municipality (non-zero flooded area) is matched to one municipality in a county without affected municipalities, exactly on East or West Germany, municipality size class, an indicator for an above-median wage and an indicator for a local economic downturn, and by Mahalanobis distance on the other characteristics; Dresden and Leipzig are matched to West German cities. Difference: mean difference within pairs, standard errors clustered by the county of the affected municipality in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. "–": exact-matching variable. *Source:* INKAR (BBSR), Federal Statistical Office, IAB establishment and employment data aggregated to municipalities and counties.

Table A29: Matched municipalities

	2002	2013	2021
Affected municipalities	302	261	266
Matched pairs	302	261	265
of which Dresden or Leipzig, matched to West German cities	2	1	0
Counties of the affected municipalities	25	45	32
Counties of the control municipalities	38	59	47
Federal states of the affected municipalities	4	8	3
Federal states of the control municipalities	8	12	8
Affected municipalities in West Germany (%)	1.3	42.5	100.0
Pairs in the same federal state (%)	24.5	42.9	47.2
Affected municipalities flooded in an earlier flood (%)	–	38.3	0.0

Notes: Affected municipalities: municipalities with a non-zero flooded area. Each affected municipality is matched to one control municipality in the year before the flood (Appendix C); Dresden and Leipzig are matched separately to West German cities. *Source:* flood-extent maps, municipality matching data.

Table A30: Effects on workers in comparison: natural disasters

Country	Event	Study	Exposed group	Unit	Earnings (%) Year 1	Earnings (%) Year 3	Employment (pp) Year 1	Employment (pp) Year 3
This paper								
Germany	Flood, 2021		Indirectly affected: municipality hit, home and workplace dry	Individual	−0.3		−0.6	
			Directly affected: home or workplace flooded	Individual	−2.2		−1.7	
			home only		−4.8		−3.4	
			workplace only		+0.4		+0.8	
			home and workplace		−3.0		−4.0	
Natural disasters								
USA	Hurricane Katrina, 2005	Deryugina et al. (2018)	Residents of New Orleans, regardless of own damage	Individual	−9.5	+5.4	−4.2	−1.3
USA	Hurricanes Katrina and Rita, 2005	Groen et al. (2020)	Workers living in hit counties	Individual	−3.0	+3.5	–	–
			home in a block with major / minor damage		−17.2 / −6.4	−3.1 / +3.0	–	–
			workplace in a block with major / minor damage		−14.6 / −7.6	0.0 / +2.9	–	–
Iceland	Volcanic eruption, 1973	Nakamura et al. (2022)	Residents aged 25+ whose house was destroyed (vs. house not destroyed)	Individual	Years 8–41: −2.6		–	–
Australia	Weather disasters, 2009–2018	Johar et al. (2022)	Own home damaged or destroyed	Individual	−2.4[a]	–	+0.4[b]	–
USA (Florida)	19 hurricanes, 1988–2005	Belasen and Polachek (2009)	Counties hit directly	County	−0.2	+0.4[c]	−2.9%	−4.3%[c]
			neighboring counties	County	−0.9	−1.1[c]	−0.4%	+0.5%[c]
USA	Hurricanes, 1982–2017	Jerch et al. (2023)	Counties hit by a major hurricane	County	–	–	Years 1–5: −4.4%	
Italy	Floods and landslides, 2013–2016	Clò et al. (2024)	Firms in hit municipalities	Firm	–	–	−4.7%	−5.1%[c]
			firms in adjacent municipalities	Firm	–	–	Years 0–2: −0.2%	

Notes: Effects relative to the comparison group of each study, in the years after the event. Earnings: effect in percent of the pre-event mean; annual or quarterly labor earnings including zeros for workers without a job. Employment: effect in percentage points; for county- and firm-level studies in percent of employment (marked %). Where a study reports effects for several groups, the group in the first row is its main sample. Studies are restricted to those published in leading general-interest and field journals that report earnings or employment effects. *This paper:* average effect over years +1 to +3 after the 2021 flood (Table 2 and Appendix Table A10). Earnings in percent of the earnings of the matched controls in the year before the flood (directly affected: EUR 36,709; indirectly affected: EUR 43,302); for the three exposure types relative to the baseline of all directly affected workers. Statistically significant at the 5% level: indirect and direct employment, direct earnings, home only and home and workplace (Appendix Table A10). *Other studies:* effects as reported or converted to percent with the baseline mean reported in the study. Nakamura et al. (2022): earnings pooled over 1981–2014. Johar et al. (2022): disaster 12–24 months before the interview. Belasen and Polachek (2009): earnings per worker and employment of the county. Job loss: Appendix Table A31. [a]Household income. [b]Full-time employment. [c]Year 2 instead of year 3. *Source:* own compilation from the studies cited; this paper: IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Table A31: Effects on workers in comparison: job loss

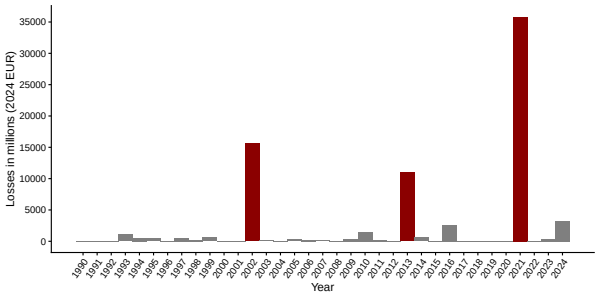
Country	Event	Study	Exposed group	Unit	Earnings (%) Year 1	Earnings (%) Year 3	Employment (pp) Year 1	Employment (pp) Year 3
This paper								
Germany	Flood, 2021		Indirectly affected: municipality hit, home and workplace dry	Individual		−0.3		−0.6
			Directly affected: home or workplace flooded	Individual		−2.2		−1.7
			home only			−4.8		−3.4
			workplace only			+0.4		+0.8
			home and workplace			−3.0		−4.0
Job loss								
USA (Pennsylvania)	Mass layoffs, 1980–1986	Jacobson et al. (1993)	Displaced workers with high tenure	Individual	−38.9	−27.3	–	–
USA (Connecticut)	Mass layoffs, 2000–2001	Couch and Placzek (2010)	Displaced workers with high tenure	Individual	−24.9	−13.9	–	–
USA	Mass layoffs, 1980–2005	Davis and von Wachter (2011)	Displaced men, in expansions / recessions	Individual	−24.7 / −39.1	−20.0 / −25.8	–	–
USA (Washington)	Mass layoffs, 2008–2010	Lachowska et al. (2020)	Displaced workers with high tenure	Individual	−35.2	−17.7	−16.1	−3.2
Germany (West)	Mass layoffs and plant closures, 1980–2005	Schmieder et al. (2023)	Displaced workers	Individual	−29.7	−20.5	−25.9[a]	−14.7[a]
Germany (West)	Employer bankruptcies, 2007–2009	Fackler et al. (2021)	Displaced workers	Individual	−26.1	−12.2	−20.9	−7.1
Germany (West)	Mass layoffs at large plants, 1981–2004	Gathmann et al. (2020)	Displaced workers (half of them aged 51–65)	Individual	–	–	−57.2	−43.3
			all workers attached to the local labor market	Individual	–	–	−0.4	−0.8

Notes: Effects relative to the comparison group of each study, in the years after the event. Earnings: effect in percent of the pre-event mean; annual or quarterly labor earnings including zeros for workers without a job. Employment: effect in percentage points. Where a study reports effects for several groups, the group in the first row is its main sample. Studies are restricted to those published in leading general-interest and field journals. This paper: as in Appendix Table A30. *Other studies:* effects as reported or converted to percent with the baseline mean reported in the study. Gathmann et al. (2020): mass layoffs of at least 500 workers at large plants in the tradable sector; employment in jobs subject to social security, so that retirement counts as non-employment; the authors attribute the losses, larger than in most of the literature, to this sample. [a]Days employed in percent of the days employed before displacement. *Source:* own compilation from the studies cited; this paper: IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

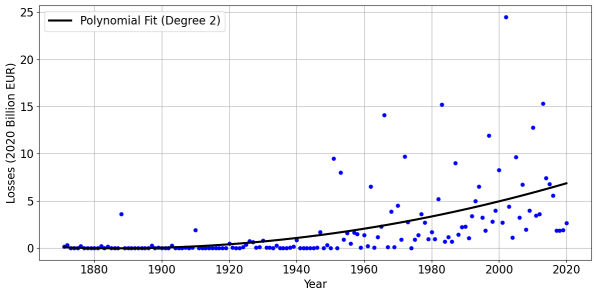
G Appendix figures

Figure A1: Why these three floods: flood losses in Germany and flood trends in Europe

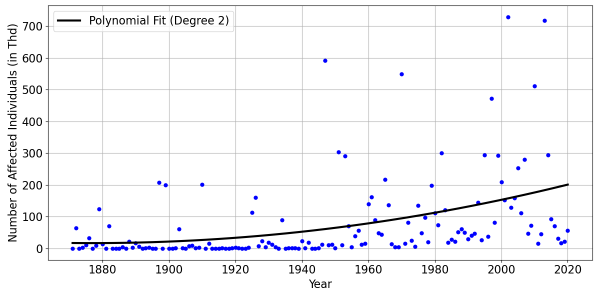
(a) Financial losses, Germany, 1990–2024



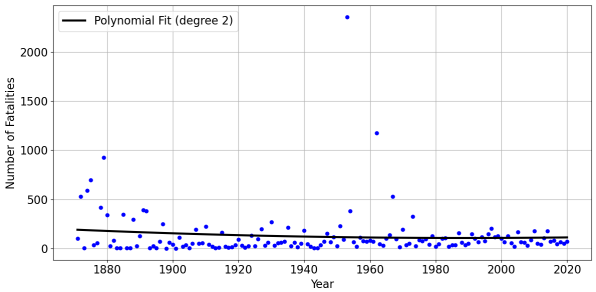
(b) Financial losses, Europe



(c) People affected, Europe

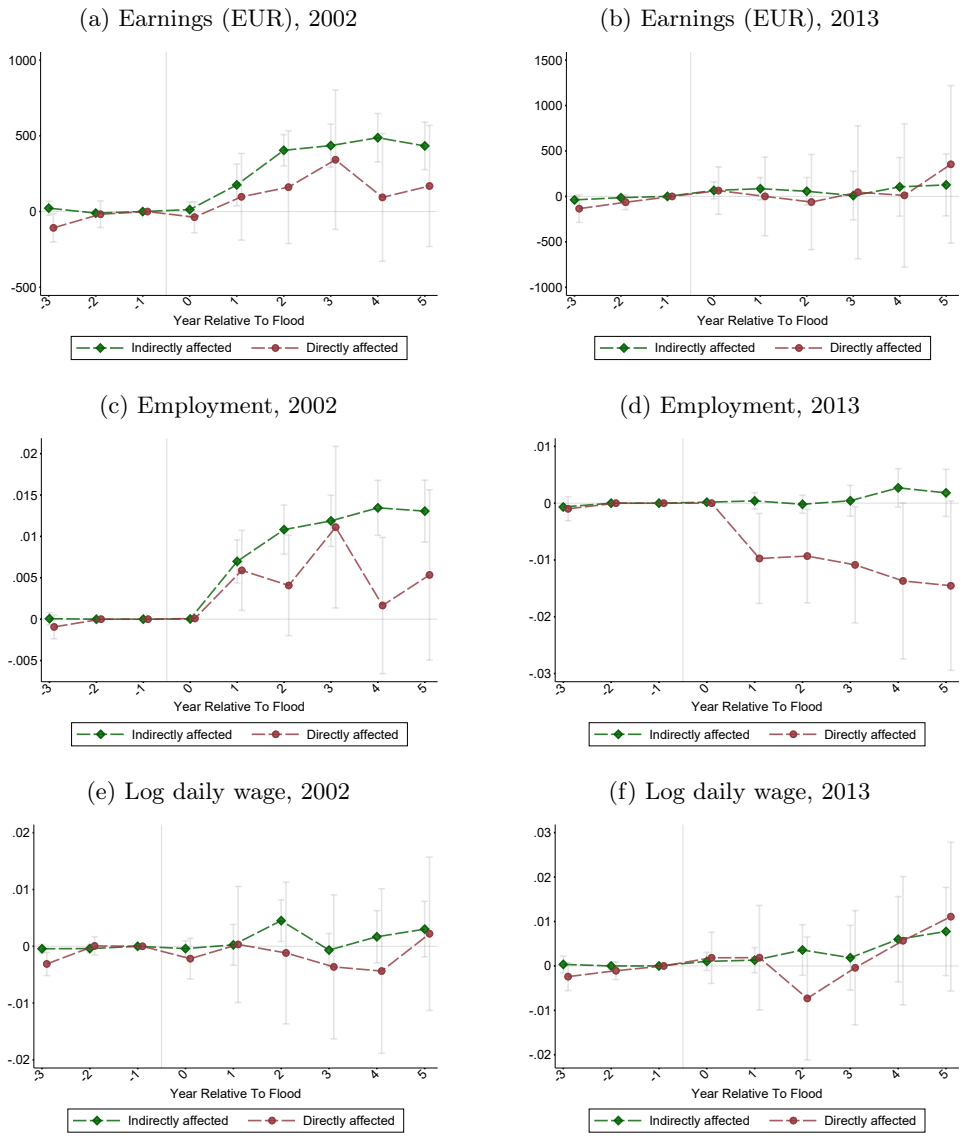


(d) Fatalities, Europe



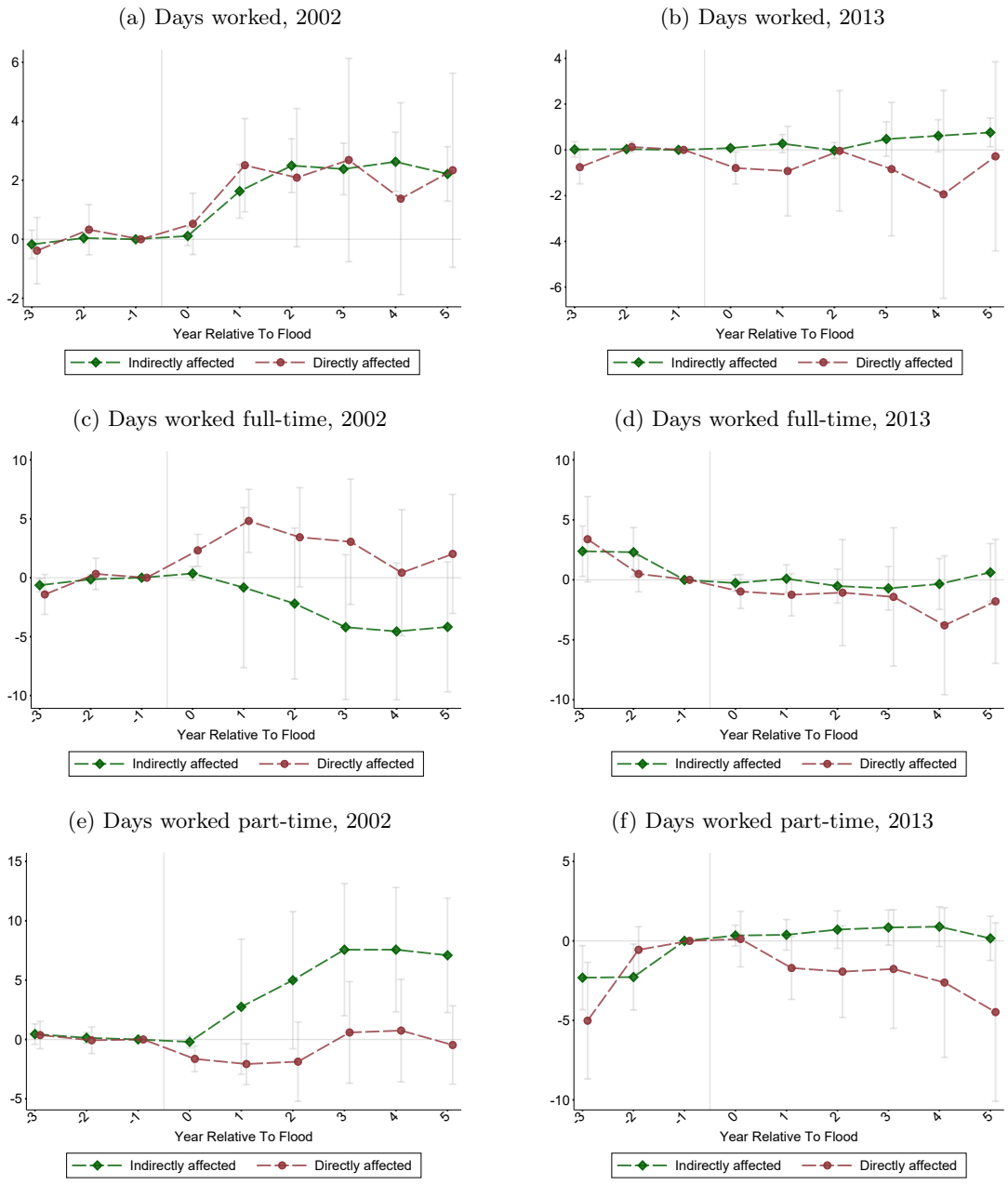
Notes: Panel (a): yearly losses from floods in Germany, 1990–2024, in millions of 2024 EUR; the years of the three floods studied in red. The yearly totals are about EUR 15.6 billion (2002), 11.0 billion (2013) and 35.8 billion (2021); the three floods alone account for 15.4, 11.0 and 35.2 billion. No other year since 1990 exceeds 3.2 billion. Panels (b)–(d): financial losses, people affected and fatalities from floods in Europe, 1870–2020, with a quadratic trend. *Source:* panel (a): HANZE database of historical flood impacts in Europe, v3.0.0 beta (Paprotny, 2025), all events in Germany starting in 1990 or later, summed by year; panels (b)–(d): HANZE v2.1 (Paprotny et al., 2024).

Figure A2: Effects of the 2002 and 2013 floods: indirectly vs. directly affected workers



Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +5; standard errors clustered at the treated municipality. Floods of 2002 (left column) and 2013 (right column). Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Yearly earnings: earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job. Employment: employed on the reference date in each year, the same calendar day as the day before the flood. Log daily wage: daily wage of the main job, observed for employed workers only. Days worked: days in employment subject to social security contributions in the calendar year. By construction of the sample, all workers are employed before the flood; event years without variation in the outcome are shown at zero without confidence interval. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

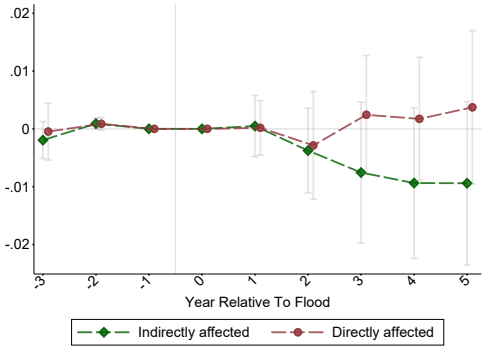
Figure A3: Days worked, 2002 and 2013 floods: indirectly vs. directly affected workers



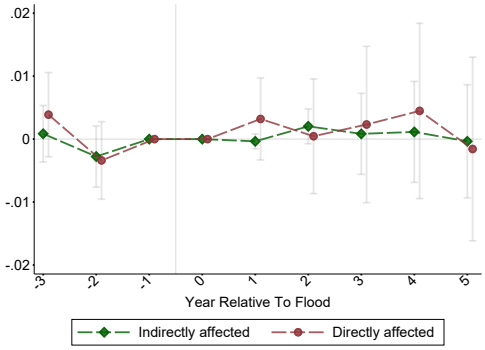
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +5; standard errors clustered at the treated municipality. Floods of 2002 (left column) and 2013 (right column). Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Days worked per calendar year in all jobs subject to social security contributions (a, b), in full-time jobs (c, d) and in part-time jobs (e, f); zero for workers without a job. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A4: Mobility, 2002 and 2013 floods: indirectly vs. directly affected workers

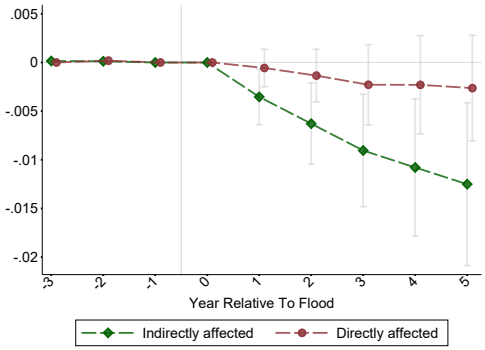
(a) Workplace county changed, 2002



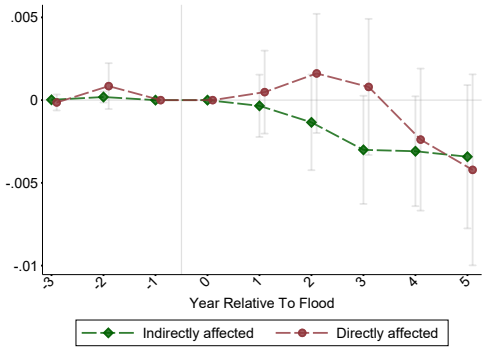
(b) Workplace county changed, 2013



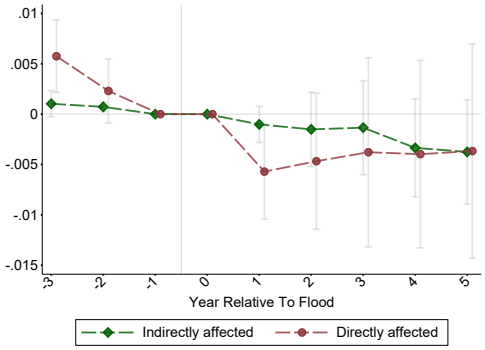
(c) Residence county changed, 2002



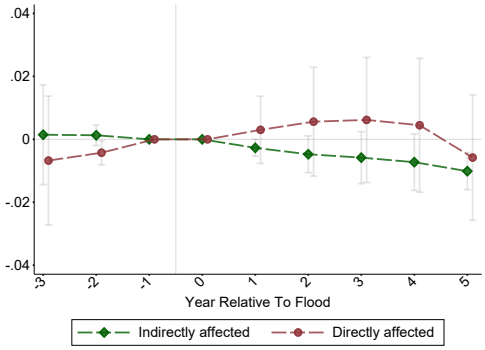
(d) Residence county changed, 2013



(e) Occupation changed, 2002



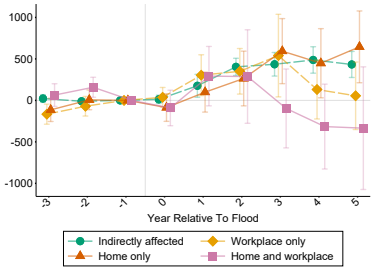
(f) Occupation changed, 2013



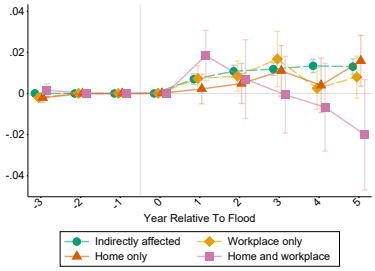
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +5; standard errors clustered at the treated municipality. Floods of 2002 (left column) and 2013 (right column). Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. The indicators equal one if the workplace county (a, b), the residence county (c, d) or the occupation (e, f) differs from that on the reference date, the day before the flood; they are missing for workers without a job (workplace county, occupation) or without a record in the data. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A5: Exposure type: 2002 and 2013 floods

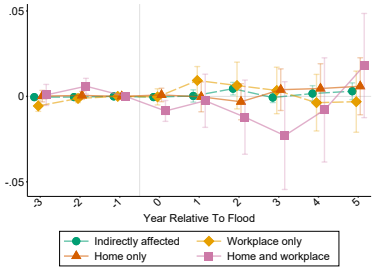
(a) Earnings (EUR) by exposure type, 2002



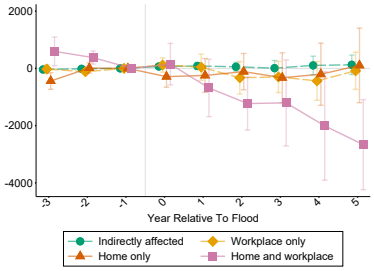
(b) Employment by exposure type, 2002



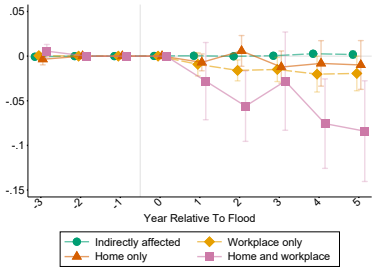
(c) Log daily wage by exposure type, 2002



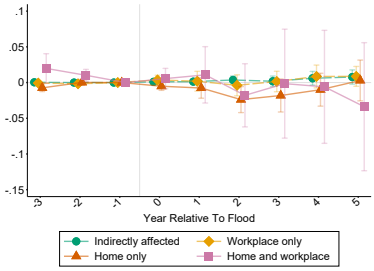
(d) Earnings (EUR) by exposure type, 2013



(e) Employment by exposure type, 2013



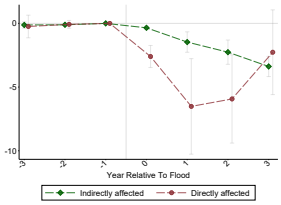
(f) Log daily wage by exposure type, 2013



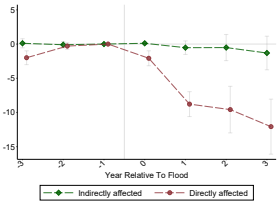
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +5; standard errors clustered at the treated municipality. Floods of 2002 (upper row, panels (a)–(c)) and 2013 (lower row, panels (d)–(f)). Exposure types as in equation (4): indirectly affected; directly affected at the workplace only, at home only, or both. Each type is estimated in a separate regression on its matched pairs; the estimates correspond to τ_0, τ_W, τ_H and τ_B in equation (2). The exposure type of the treated worker applies to the matched pair. Types with fewer than 30 treated workers or 8 treated municipalities are not shown. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Yearly earnings: earnings from all employment in the calendar year, in 2015 prices, zero for workers without a job. Employment: employed on the reference date in each year, the same calendar day as the day before the flood. Log daily wage: daily wage of the main job, observed for employed workers only. Days worked: days in employment subject to social security contributions in the calendar year. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A6: Days worked, marginal jobs, unemployment benefits and mobility, 2021

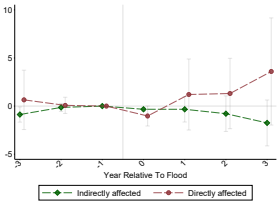
(a) Days worked



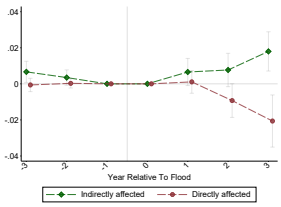
(b) Days worked full-time



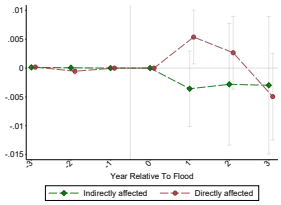
(c) Days worked part-time



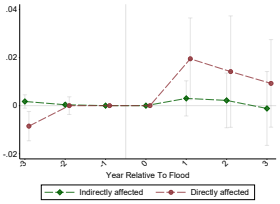
(d) Workplace county changed



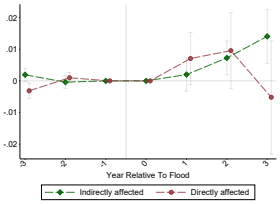
(e) Residence county changed



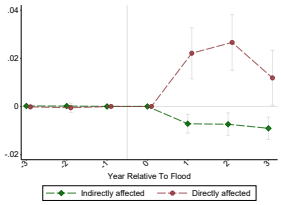
(f) Occupation changed



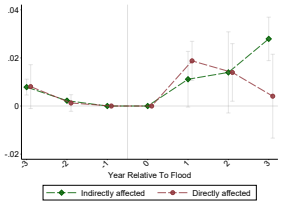
(g) Industry changed



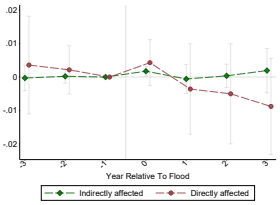
(h) Residence municipality changed



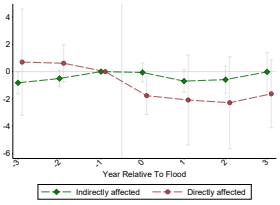
(i) Workplace municipality changed



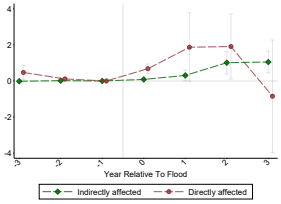
(j) Marginal side job (Minijob)



(k) Days in marginal jobs

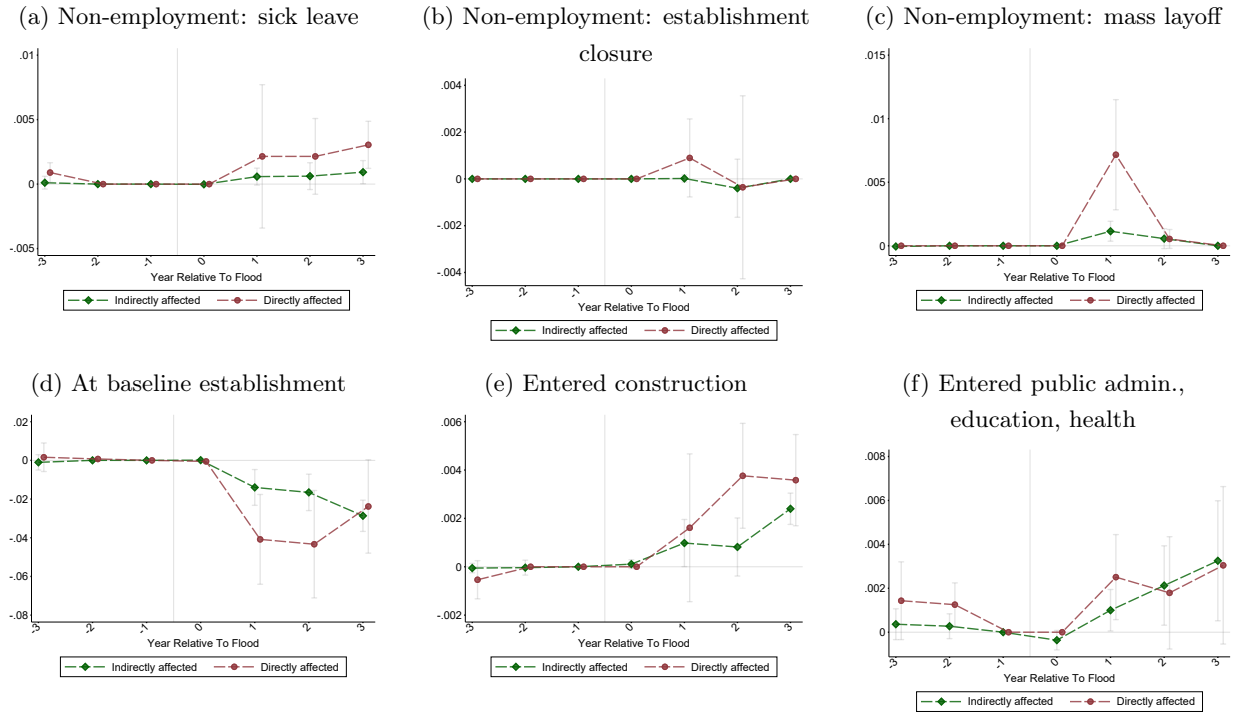


(l) Days receiving unemployment benefits



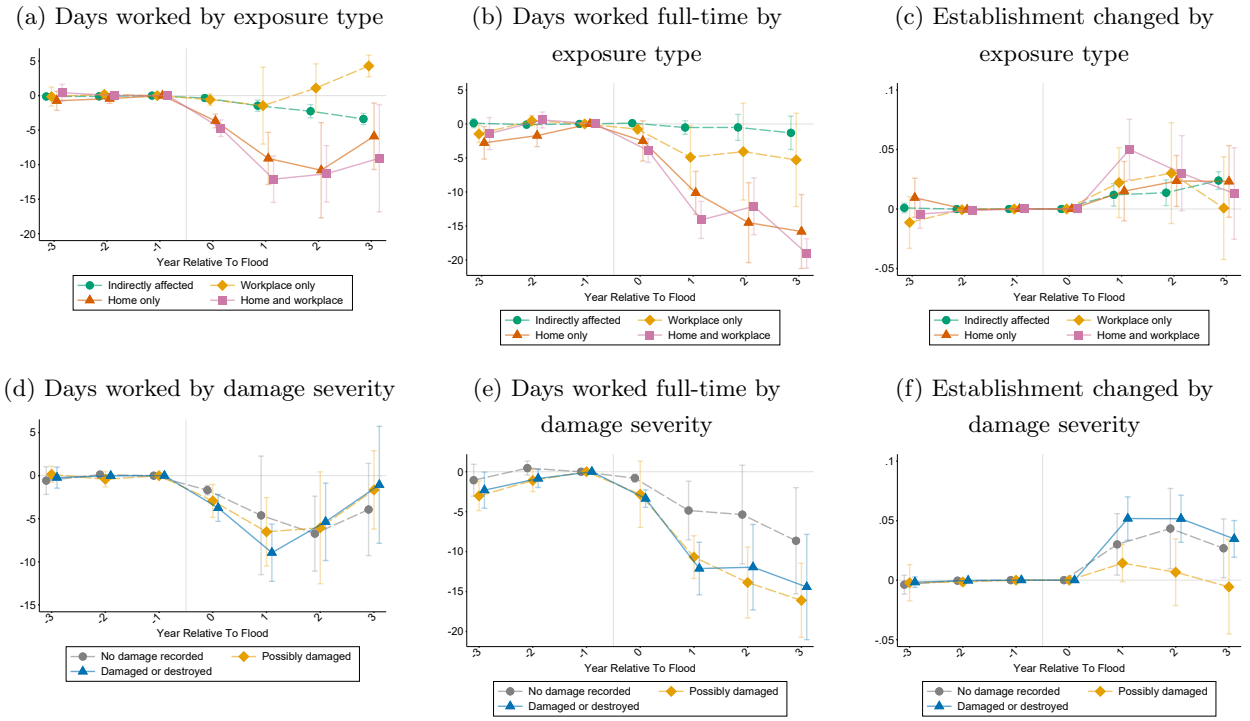
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. 2021 flood. Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Days worked per calendar year in all jobs subject to social security contributions (a), in full-time jobs (b) and in part-time jobs (c); zero for workers without a job. Panels (d)–(i): the indicator equals one if the workplace county (d), the residence county (e), the occupation (f), the industry (g), the residence municipality (h) or the workplace municipality (i) differs from that on the reference date, the day before the flood; it is missing for workers without a job (workplace and job characteristics) or without a record in the data. Panel (j): the worker holds a marginal job (*Minijob*) next to a regular job. Panel (k): days in marginal jobs per calendar year. Panel (l): days receiving unemployment benefit I (*Arbeitslosengeld I*) per calendar year. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A7: Disruption, reallocation and stimulus: event studies



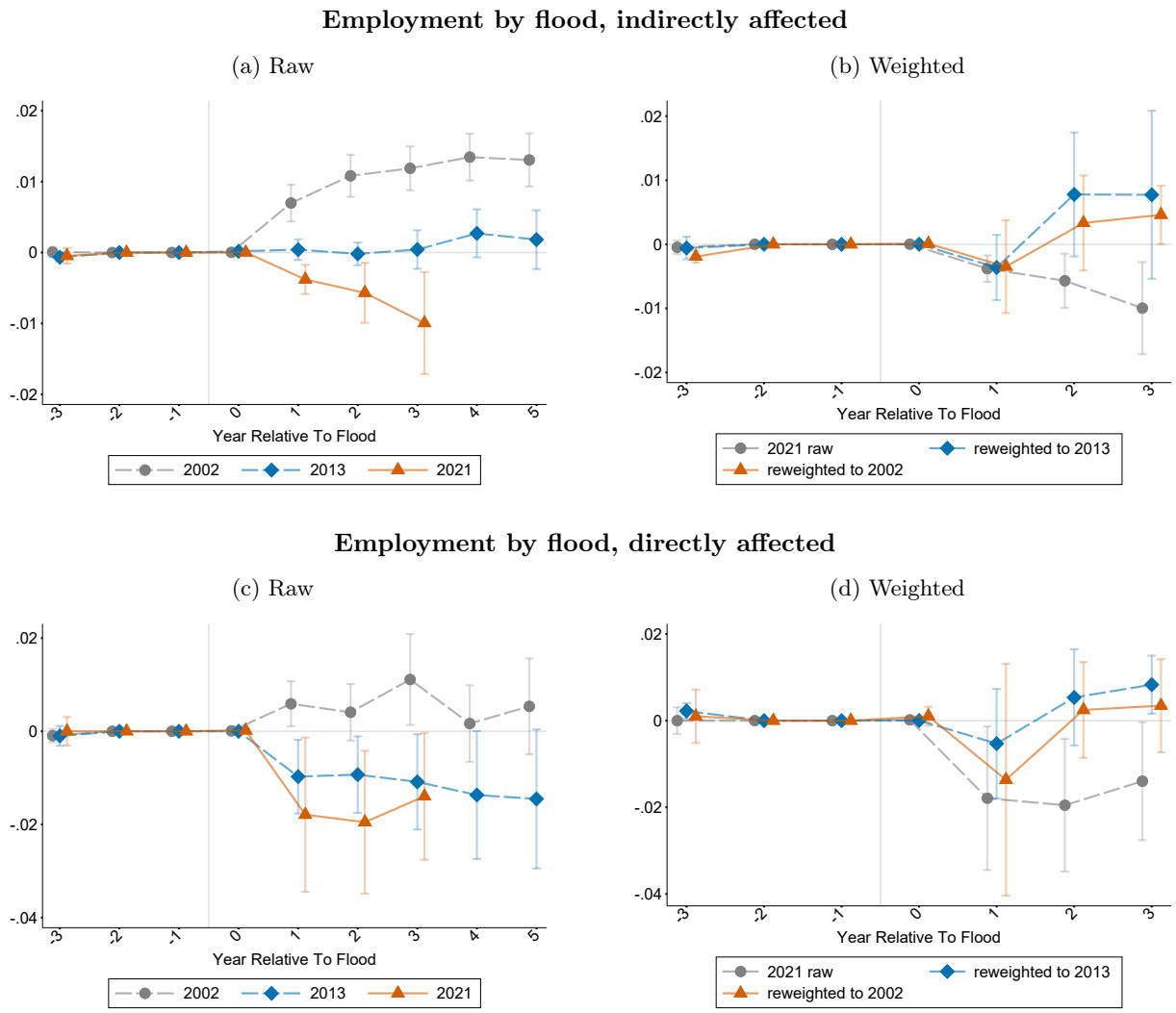
Notes: Panels (a)–(f): event-study coefficients β_k of equation (5) with 95% confidence intervals for the 2021 flood; individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Panels (a)–(c): indicator for non-employment through the channel. A worker who is not employed is assigned to the first applicable channel in the order establishment closure, mass layoff, sick leave, retirement. Establishment closure and mass layoff: the worker leaves an establishment whose employment falls by at least 90% or 30% within a year and is not employed in the following year; sick leave: the employment spell ends with a sickness-related reason code. Panel (d): employed at the establishment of year −1. Panels (e) and (f): employed in construction, or in public administration, education or health, and not in that sector in year −1. The indicators in panels (d)–(f) are zero for workers without a job. Remaining channels: Appendix Figure A14. *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

Figure A8: Days worked and establishment changes by exposure type and damage severity, 2021



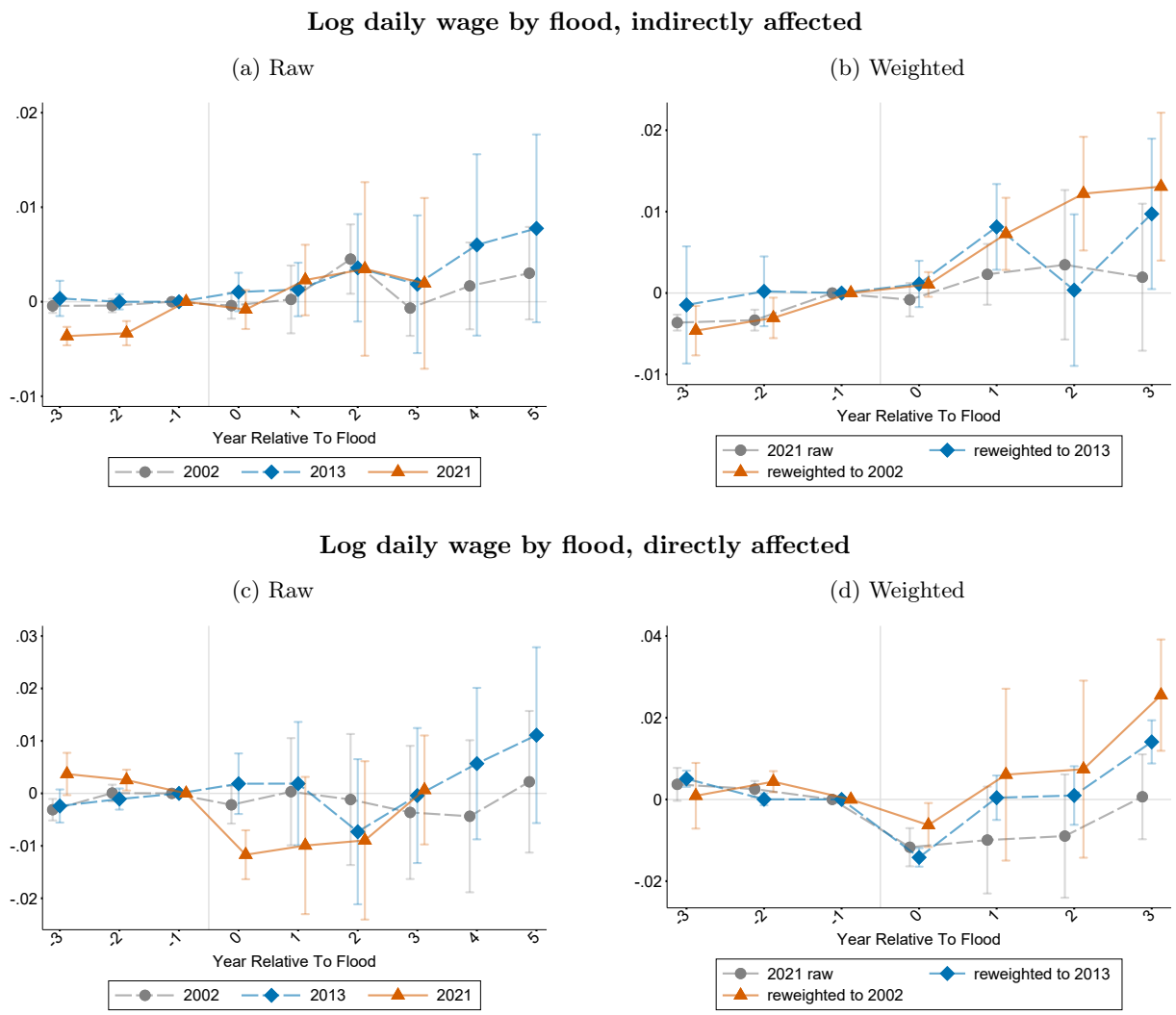
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. 2021 flood. Upper row, panels (a)–(c), exposure type: Exposure types as in equation (4): indirectly affected; directly affected at the workplace only, at home only, or both. Each type is estimated in a separate regression on its matched pairs; the estimates correspond to τ_0, τ_W, τ_H and τ_B in equation (2). The exposure type of the treated worker applies to the matched pair. Types with fewer than 30 treated workers or 8 treated municipalities are not shown. Lower row, panels (d)–(f): damage severity: directly affected workers by the Copernicus damage grade of their flooded residence (residence-matched pairs) or workplace (workplace-matched pairs). A place receives the grade of the nearest graded building within 10 meters; "no damage recorded": inside an area assessed by Copernicus, but no graded building within 10 meters; "damaged or destroyed" combines the two highest grades (only 15 treated workers live or work in a destroyed building). Directly affected workers outside the assessed areas are not used. Days worked per calendar year in all jobs subject to social security contributions (a, d) and in full-time jobs (b, e); zero for workers without a job. Establishment changed (c, f): employed at an establishment other than on the reference date, the day before the flood. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps, Copernicus EMS damage grading (EMSR517).

Figure A9: Employment effects across floods: event studies by flood and after reweighting



Notes: As Figure 4, for employment: employed on the reference date in each year, the same calendar day as the day before the flood. By construction of the sample, all workers are employed before the flood. Event-study coefficients β_k of equation (5); reference year -1; standard errors clustered at the treated municipality. Upper row: indirectly affected workers; lower row: directly affected workers. Raw: the floods of 2002 (gray), 2013 (blue) and 2021 (orange). Weighted: the 2021 flood, unweighted and reweighted to the workers affected in 2013 (West Germany only) or 2002 with propensity-score odds weights (DiNardo et al., 1996). *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A10: Wage effects across floods: event studies by flood and after reweighting



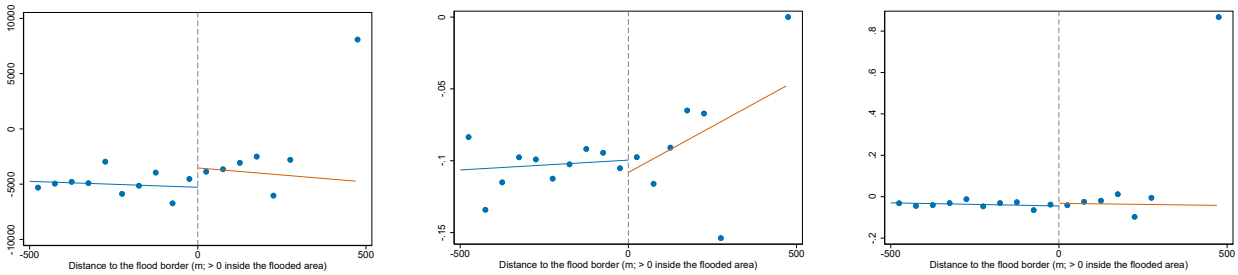
Notes: As Figure 4, for the log daily wage of the main job, observed for employed workers only. Event-study coefficients β_k of equation (5); reference year -1; standard errors clustered at the treated municipality. Upper row: indirectly affected workers; lower row: directly affected workers. Raw: the floods of 2002 (gray), 2013 (blue) and 2021 (orange). Weighted: the 2021 flood, unweighted and reweighted to the workers affected in 2013 (West Germany only) or 2002 with propensity-score odds weights (DiNardo et al., 1996). *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A11: Spatial RDD at the border of the flooded area, 2021

(a) Workplace: change in earnings (EUR)

(b) Workplace: change in employment

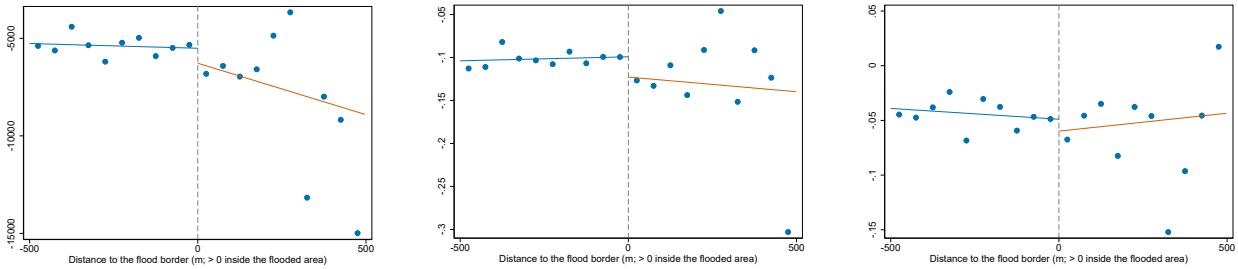
(c) Workplace: change in log daily wage



(d) Residence: change in earnings (EUR)

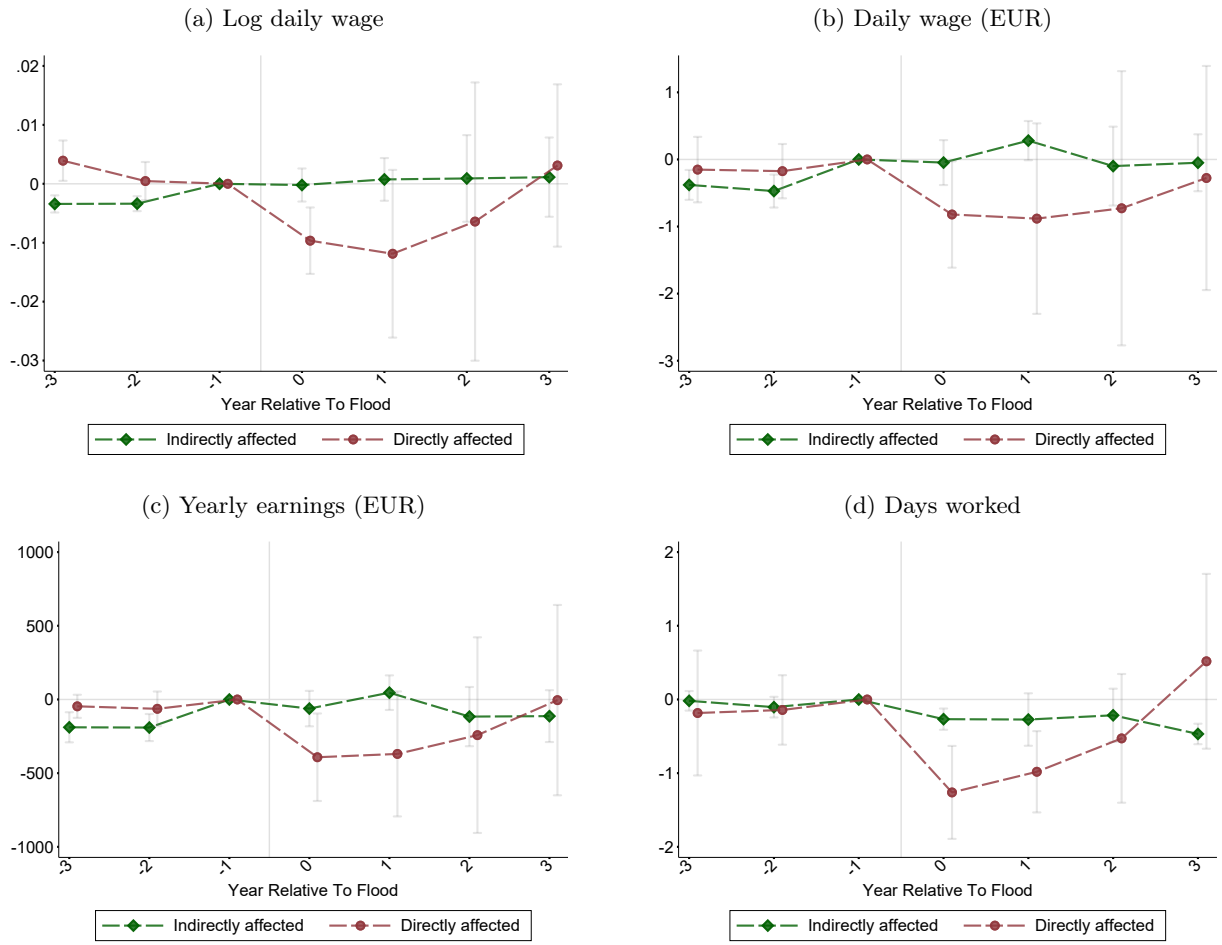
(e) Residence: change in employment

(f) Residence: change in log daily wage



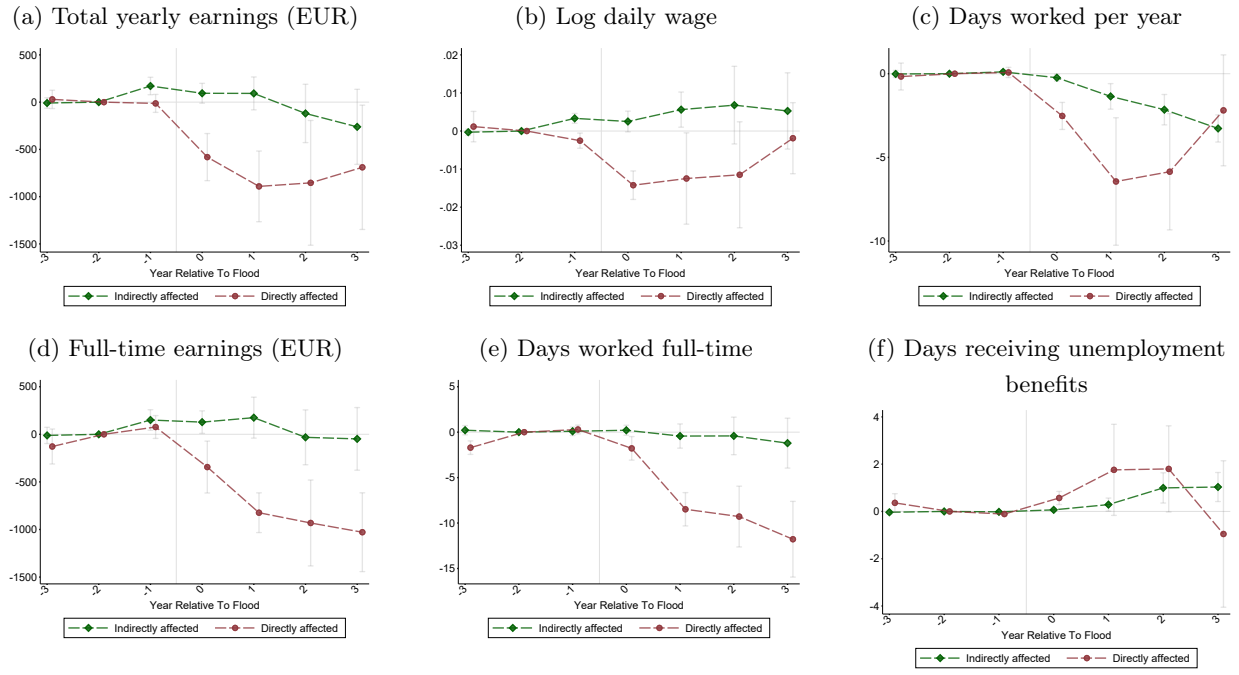
Notes: Spatial regression discontinuity design at the border of the flooded area, 2021 flood. Sample: treated workers within 500 meters of the border, in the same affected municipalities; no control municipalities are used. Panels (a)–(c): workplace-matched sample without workers whose residence was flooded, by the distance of the workplace to the border; panels (d)–(f): residence-matched sample without workers whose workplace was flooded, by the distance of the residence to the border. Distance positive inside the flooded area. Outcome: individual change between the mean in the years before (−3 to −1) and after (+1 to +3) the flood. Dots: mean change in 50-meter bins of the distance; lines: linear fits on each side of the border. The jump at the border is estimated by local linear regression with a triangular kernel and separate slopes on each side; estimates by bandwidth and placebo tests for pre-determined characteristics: Appendix Table A24. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A12: Wages of stayers, 2021: pairs employed in every year



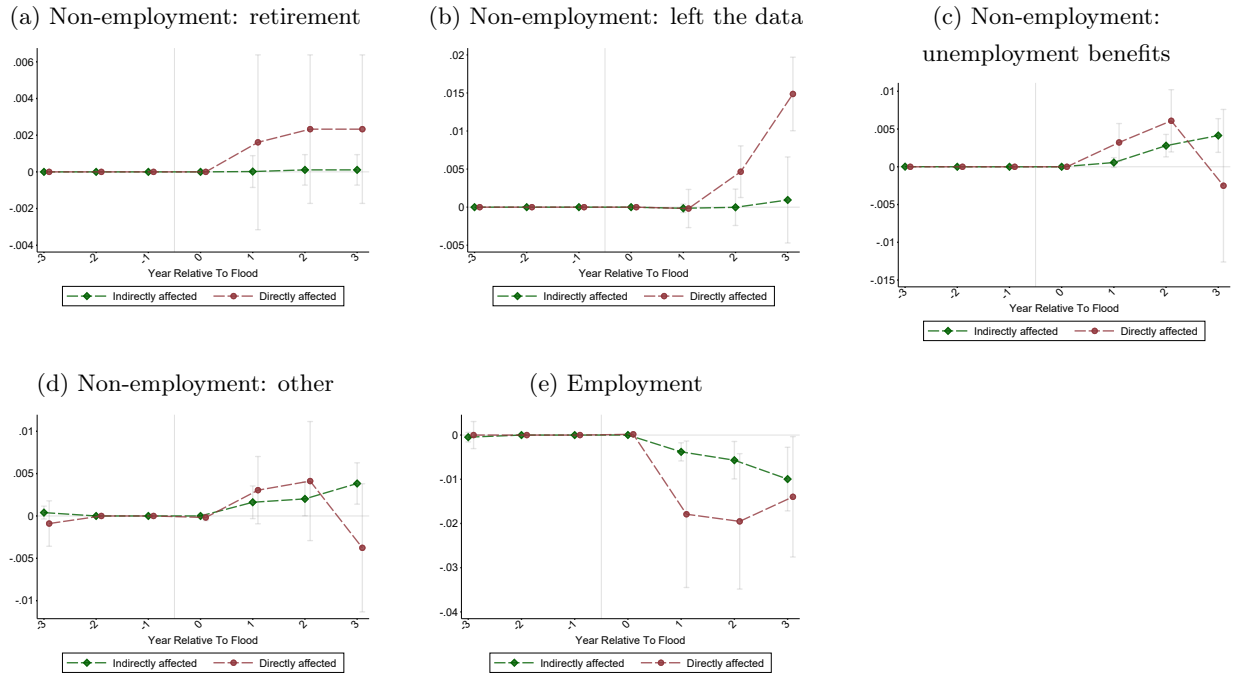
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals: regressions of the outcome on treated × event-year indicators with individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. 2021 flood, restricted to matched pairs in which both workers are employed in every year from −3 to +3, so that wages are observed throughout. Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Log daily wage and daily wage (in 2015 prices) of the main job; yearly earnings from all employment; days worked in all jobs subject to social security contributions. Wage effects similar to those in Figure 2 indicate that the wage results are not driven by selection into employment. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A13: Effects of the 2021 flood with 2019 as reference year



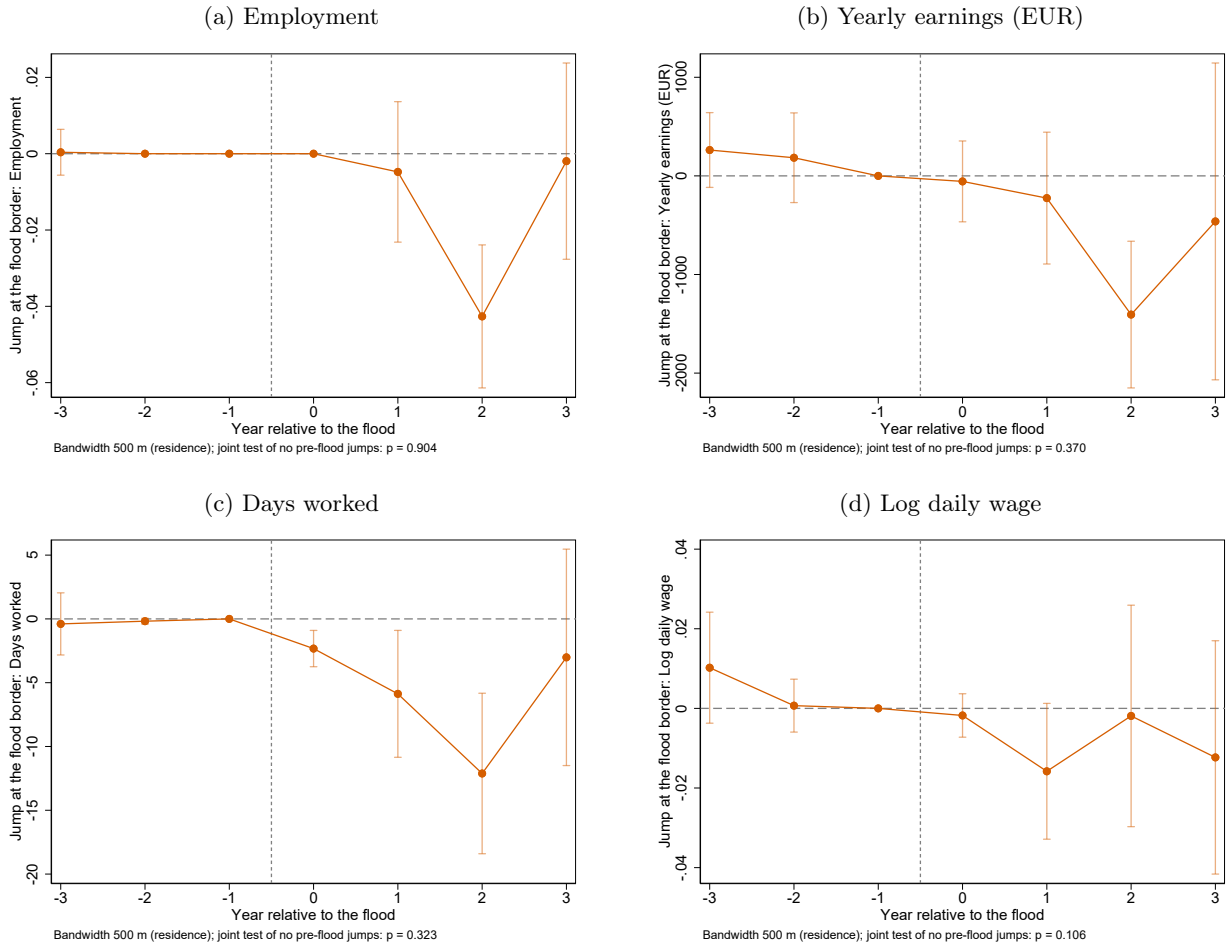
Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals, 2021 flood, with year −2 (2019) instead of year −1 (2020, the first year of the COVID-19 pandemic with widespread short-time work) as reference year; individual and matched-pair × year fixed effects; event years −3 to +3; standard errors clustered at the treated municipality. Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Yearly earnings from all employment and from full-time jobs, in 2015 prices; log daily wage of the main job (employed workers only); days worked in all jobs subject to social security contributions and in full-time jobs; days receiving unemployment benefit I. Employment equals one in all pre-flood years by construction of the sample and is not shown. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A14: Further channels of non-employment



Notes: Event-study coefficients β_k of equation (5) with 95% confidence intervals for the 2021 flood; individual and matched-pair × year fixed effects; reference year −1; event years −3 to +3; standard errors clustered at the treated municipality. Indirectly affected workers in green, directly affected workers in maroon. Directly affected: residence or workplace inside the flooded area; indirectly affected: residence or workplace in an affected municipality, but outside the flooded area. Each group is compared with its matched control workers from unaffected municipalities. Panels (a)–(d): indicator for non-employment through the channel. A worker who is not employed is assigned to the first applicable channel in the order establishment closure, mass layoff, sick leave, retirement (panels (a)–(c) of Appendix Figure A7); the remaining non-employed workers are split into "left the data", "unemployment benefits" and "other". Retirement: aged 62 or older in 2021 and no record in the data in 2022–2024. Left the data: no record in the data in the calendar year (self-employment, civil service, moving abroad, death, early or disability pension). Unemployment benefits: at least one day of unemployment benefit I in the calendar year. Other: still in the data without unemployment benefit I, e.g. recipients of basic income support only. Panel (e): employment on the reference date; employment and all channel indicators add up to one. *Source:* IEB with geocoded residence and workplace addresses, Establishment History Panel (BHP) (IAB), flood-extent maps.

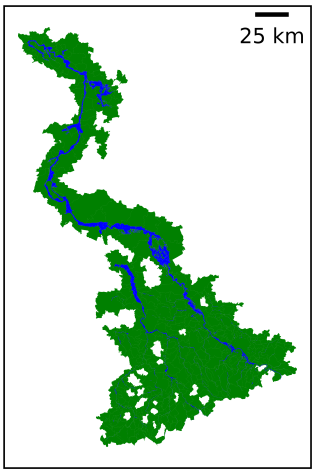
Figure A15: Spatial RDD at the border of the flooded area, by year: residence, 2021



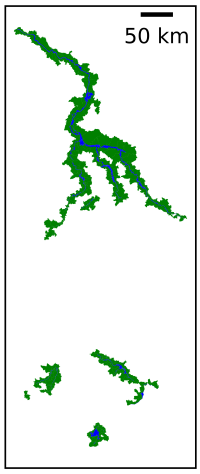
Notes: Event-study version of panels (d)–(f) of Appendix Figure A11: treated workers of the 2021 flood in the residence-matched sample within 500 meters of the border of the flooded area, without workers whose workplace was flooded; no control municipalities are used. For every year, the jump at the border in the worker's change relative to year −1, from one stacked local linear regression with a triangular kernel and separate intercepts, jumps and slopes on each side of the border for every year; 95% confidence intervals, standard errors clustered at the treated municipality. Jumps before the flood are placebo tests; the note in each panel gives the p-value of the joint test that they are zero. Year 0 is the flood year: employment refers to the day before the flood, earnings and days worked to the whole calendar year. Estimates: Appendix Table A25. *Source:* IEB with geocoded residence and workplace addresses (IAB), flood-extent maps.

Figure A16: Floods, exposure and damage

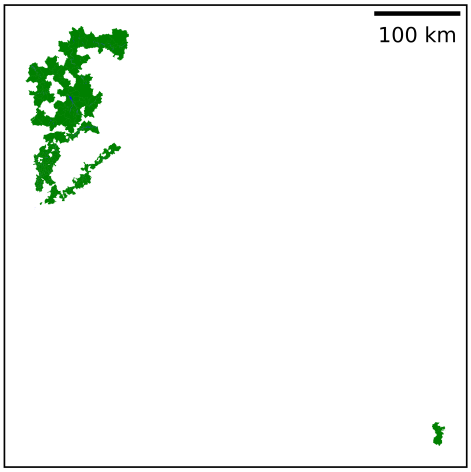
(a) 2002



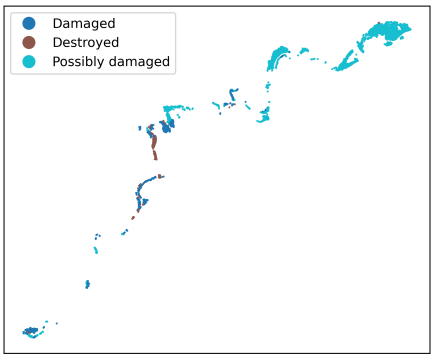
(b) 2013



(c) 2021



(d) Ahr valley 2021: building damage



Notes: Panels (a)–(c): flooded area in blue, affected municipalities in green. Panel (d): buildings along the Ahr around Bad Neuenahr-Ahrweiler by Copernicus EMS damage grade (possibly damaged, damaged, destroyed); outside the assessed areas the damage status is unknown. *Source:* flood-extent maps, Copernicus EMS (EMSR517); own illustration.