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Kurzarbeit and natural disasters: How effective are short-time working allowances in avoiding unemployment?

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There is substantial evidence on the effectiveness of short-time work on reducing unemployment. However, no study looks at its role during natural disasters. This article exploits the exogenous nature of the 2013 European floods to assess if the impact depends on the quality of the short-time work mechanism across affected counties. We use regression discontinuity designs to show that unemployment does not increase in regions with robust programs while rising up to seventeen percent in areas with less robust mechanisms. Our results are relevant to the literature on how institutional quality influences recovery and suggests that short-time work programs are useful against unforeseeable productivity shocks besides financial crises.

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1. Introduction

In May and June 2013, extreme precipitation caused many Central European rivers to overflow, inundating several urban, industrial, and agricultural areas across Austria, the Czech Republic, Germany, Hungary, and Slovakia. Studies of this event show evidence of its effects on the transportation network (Fournier Gabela and Sarmiento, 2020), industrial production (in den Bäumen et al., 2015; Oosterhaven and Többen, 2017), insurance claims (Munich RE, 2014), and general infrastructure (Thieken et al., 2016). Following the literature on how institutions can influence recovery after a natural disaster (Cavallo et al., 2013; Barone and Mocetti, 2014), in this article, we exploit differences in short-time work programs across affected nations to understand the ability of these mechanisms to dampen the adverse consequences of natural disasters on employment.¹

Natural disasters decrease the productivity of firms through several channels, including capital destruction, supply chain interruptions, and demand-side pressures. Lower productivity forces affected companies to reduce their labor demand (total work hours) through layoffs (extensive margin) or reduced working time (intensive margin). The absence of wage support mechanisms promoting adjustments via the intensive margin can lead to inefficient separations and unequal distribution of uncertainty among the workforce (Van Audenrode, 1994; Arpaia et al., 2010). Short-time work programs aim to stabilize labor markets by avoiding involuntary dismissals, fostering labor hoarding, and encouraging work-sharing. They work through direct government transfers providing wage support to firms in financial distress and are complements to other working-time flexibility instruments.² However, compared to other alternatives, short-time work provides help to firms in financial difficulties by freeing them from paying wages for non-worked hours. It is a substitute for labor adjustments via the extensive margin and a superior strategy depending on the nature of the shock (Rinne and Zimmermann, 2012).

Studying the adequacy of short-time work mechanisms under different conditions

¹Alternative names for short-time work programs are short-time compensation systems and job retention schemes.

²In Germany and Austria, firms must first exhaust alternative flexibility instruments before commencing short-time work (Eurofound, 2010a).

is essential for improving future program design. For instance, gained insights can help orientate efforts to alleviate the impacts of other types of catastrophes, such as the COVID-19 outbreak. Furthermore, studies on the economic consequences of repetitive events, like floods, are highly relevant because climate change will exacerbate both the frequency and intensity of natural disasters around the globe (IPCC, 2012). In particular, climate change is likely to increase the number of Central European floods because of its effect on European weather patterns (Jongman et al., 2014).

Existing studies on the effect of natural disasters on unemployment find negative impacts in affected regions during the immediate aftermath of the disaster (Belasen and Polachek, 2008; Ewing et al., 2009; Xiao and Feser, 2014; Brown, 2006). Natural disasters affect labor markets because physical damage can hinder normal working conditions while creating structural changes, mismatches between workers and firms, as well as barriers to the demand and supply of labor (Venn, 2012). Examples include the evacuation of people, workers who cannot arrive at work, the incapacity to work because of damage to buildings or machinery, as well as firms that cannot operate because of supply chain problems.

Early contributions on the labor market effects of short-time work indicate that German firms using this instrument display less employment volatility (Deeke, 2005). Abraham and Houseman (1993); Van Audenrode (1994) show that countries with generous short-time work programs achieve a high speed of adjustment in total working hours to changes in output.³ This is possible because short-time work effectively compensates for firing restrictions consequence of strict employment protection legislation. The strictness of employment protection increases the probability of participating in short-time work programs, while the generosity of unemployment benefits works in the opposite direction (Van Audenrode, 1994; Boeri and Bruecker, 2011; Cahuc and Carcillo, 2011). Although the average contribution of the intensive margin to Germany's labor adjustment was close to 50% during historic recessions, the use of these adjustments reached unprecedented levels during the 2008 financial crisis in this country and other advanced nations (Boeri and Bruecker, 2011).

³The level of generosity refers to workers' current income under short-time work as a percentage of their previous (regular) income.

During the 2008 financial crisis, despite large drops in output, unemployment levels in countries with high short-time work participation were far from being proportionally affected, with the German case standing out as a miracle (Messenger, 2009).⁴ The primary source of adjustment for the German labor market was a reduction in working hours along the intensive margin, with short-time work as the main protagonist (Burda and Hunt, 2011; Sacchi et al., 2011; Balleer et al., 2016). Hijzen and Venn (2011); Boeri and Bruecker (2011); Hijzen and Martin (2013) give empirical evidence that short-time work helped preserve jobs in OECD countries during the 2008 financial crisis. However, the number of jobs saved was lower than the number of full-time equivalents, indicating the existence of dead-weight losses, which occur when short-time hours finance hour reductions that would have happened in any event or that would not have existed in the absence of the subsidy.⁵

However, evidence showing that crises previous to 2008 saw unemployment increases in Germany despite short-time work motivates the search for alternative explanations to the German miracle (Möller, 2010; Boysen-Hogrefe and Groll, 2010; Burda and Hunt, 2011; Rinne and Zimmermann, 2012; Dustmann et al., 2014). These studies show that besides working time flexibility, the miracle resulted from a series of business cycle conditions and asymmetries in how the crisis affected each country. While, in Germany, most of the affectation accrued to the 2008 financial crisis happened in sizeable export-oriented manufacturing companies, in the USA, most of the affectation was related to housing market conditions.

Besides short-time work, other remarkable working time flexibility instruments in Germany during the 2008 financial crisis included working-time accounts and weekly working time reductions (Möller, 2010; Bogedan et al., 2009; Fuchs et al., 2010; Schneider and Graef, 2010).⁶ An analysis based on the 2009 European Company Survey shows that European firms do not use flexibility measures in isolation, rather these are combined to different degrees (Eurofound, 2010b). The study also constructs com-

⁴Hoffmann and Lemieux (2016) show that there is no German miracle when using data until 2011. However, there is still a German puzzle: employment barely declined early in the crisis despite a sharp fall of GDP.

⁵Full-time equivalents are a fictitious number giving the potential number of full- and part-time jobs saved due to the implementation of short-time work.

⁶In Germany, working time reductions are possible thanks to sector-specific opening clauses that allow for non-compensated working hours reductions up to 25% (Bispinck, 2009).

pany profiles according to the previous flexibility degrees and shows that each profile type exists in every country. Despite this, a survey of German works councils in 2009 reveals that, relative to other instruments, the most substantial difference between affected and unaffected firms was in the use of short-time work (Bogedan et al., 2009). This result is in line with Boeri and Bruecker (2011), who show that working time accounts did not suffer a significant increase during the crisis, implying that it is not an instrument for short-time economic shocks but rather for the ups and downs of the business cycle. A further important consideration is that mechanisms other than short-time work do not apply to firms with liquidity problems as firms still need to continue paying wages. Evidence along these lines indicates that firms without financial frictions relied less intensively on short-time work during the 2008 financial crisis (Bohachova et al., 2011).

Although the 2008 financial crisis and the 2013 floods fulfill the omnipresent short-time work eligibility condition requiring that shocks are "unexpected, inevitable, and temporary," there are significant differences in how each affected firms and labor markets. The shock imposed by the 2013 floods was unrelated to the business cycle and different in nature, duration, and spatial extent to the financial crisis. The floods shocked regions in the same way, through inundations of varying intensities. Their effect did not concentrate on specific sectors, curtailed local demand, and caused capital destruction. It affected many neighboring border regions whose economies, despite different national regulations, have many common characteristics. Moreover, the shock had a much shorter duration of, at most, a couple of weeks. A transient shock decreases uncertainty, favors labor hoarding, makes layoffs almost the only available extensive margin flexibility instrument, and makes dismissals more difficult under strict employment protection legislation.⁷

Germany and Austria have long-standing experience with short-time work, shared similar generous program features, and developed tailored programs to support companies in flooded areas by reducing requirements and further increasing generosity. On the contrary, while the Czech Republic and Slovakia used these mechanisms for the

⁷Other popular extensive margin instruments include letting fixed-term contract expire, stop hiring, and early retirement schemes (Bogedan et al., 2009).

first time during the 2008 financial crisis, Hungary did not have any active program in 2013. Further, while Austria, Germany, and Slovakia share similarities concerning the strictness of employment protection and unemployment benefits, the institutional setting impedes (facilitates) extensive margin adjustments in the Czech Republic (Hungary).

This study is the first examining the effectiveness of short-time work programs for shocks other than the 2008 financial crisis. Can a labor market instrument capable of saving hundreds of thousands of jobs throughout economic crises prevent unemployment during a natural disaster? Given the shock characteristics of the 2013 floods and evidence indicating that nations with robust short-time work programs (Boeri and Bruecker, 2011; Cahuc and Carcillo, 2011; Rinne and Zimmermann, 2012) and experience in implementation (Boeri and Bruecker, 2011; Rinne and Zimmermann, 2012) achieve higher participation rates, we propose that different labor market outcomes in each of the flooded countries are due to differences in the program features.⁸

To estimate the floods' impact, we use a local-linear regression discontinuity in time (RDiT) design (Hausman and Rapson, 2018). Studies employing a similar quasi-experimental approach include several areas such as transportation (Anderson, 2014; Burger et al., 2014), health (Toro et al., 2015), and environmental economics (Grainger and Costello, 2014). Compared to the traditional regression discontinuity design, RDiT uses time as the running and treatment assignment variables. In other words, it estimates the discontinuity in the flooded month by comparing the dependent variables just before and after it. To avoid bias from correlated temporal unobservables, we use the augmented version of RDiT (ARDiT), as suggested in Hausman and Rapson (2018). The main idea behind the ARDiT is to divide the estimation procedure into two steps, one initial regression taking away the time variation in the dependent variable and a second regression using the residuals from the first step in a RDiT framework. It is necessary to use an ARDiT specification because using variables over a large time window increases the risk of having biased estimates arising from unobserved time-varying factors. We test for the robustness of the design with a placebo

⁸Generosity and experience also raise participation rates for other social programs (McLaughlin, 1987; Hernanz et al., 2004).

test studying the effect of the flood on unaffected European countries.

We begin by exploring the effect of the floods on short-time work participation in Germany. The results show that companies and employees in Germany actively used the short-time work mechanism during the floods; the number of short-time companies and the number of short-time employees increasing by 29% and 25%, respectively. Afterward, we examine how the inundations affected the unemployment rates of five Central European countries afflicted by the floods. In line with our expectations, countries with robust programs suffered no significant effects while uncovering negative consequences for the other affected Central European countries. For the Czech Republic, Hungary, and Slovakia, the flood increases regional unemployment in flooded counties by 7%, 9%, and 6%, respectively. To determine if the German labor market's stability is related to its robust short-time work program, we re-estimate the flood effects for all variables using different flood extent intensities. As we reduce the sample to include only those regions with a larger flooded area, we find that Germany's short-time work participation increases further up to 75%. As expected, while unemployment remains unaffected in Germany and Austria, it further increases to 14%, 17%, and 9% in the other flooded countries, respectively.

Our findings suggest that well-designed short-time work programs can flatten the negative impact of natural disasters on employment, implying that these programs can also be useful in the case of short-lived events, including famines, pandemics, or terrorist attacks. Our findings support arguments in favor of implementing short-time work programs in countries where they do not exist and to the adjustment of already implemented programs during periods of unforeseeable productivity shocks.

2. Background

2.1. Theoretical background

2.1.1. A labor market model under disaster risk

To provide intuition into the effect of unexpected natural disasters on unemployment and describe how short-time work programs can support labor markets in adjusting

against these types of shocks, we develop a simplified model with endogenous job separations arising from natural disaster shocks. The model is based on the Diamond (1982) and Mortensen and Pissarides (1994) search and matching frictions framework, which is also used by Cooper et al. (2017) and Balleer et al. (2016) to study the effects of short-time work.

In this model, employed and unemployed make up the labor force L . Workers are homogeneous, risk-neutral, immortal, and their utility evolves linearly with wages. Each firm needs only one worker to produce. However, each firm's production process is subject to exogenous natural disaster shocks, which reduce the firm's productivity through several channels, including capital destruction, supply chain interruptions, decreases in demand, and labor supply restrictions. The disaster shock γ affects the firm's productivity $p(h)$ through $(1-\gamma) \cdot p(h)$. The larger the γ coefficient, the larger the productivity reduction. We assume that γ is a random variable drawn from a fixed and strictly increasing distribution $F(\gamma) \forall \gamma \in [\underline{\gamma}, \bar{\gamma}]$. The lower end of the interval equals zero, thus denoting the absence of a disaster shock. The upper end equals one. A cut-off shock value $\tilde{\gamma}$ determines job destruction such that whenever $\gamma > \tilde{\gamma}$, the firm will destroy the match. λ denotes the Poisson probability that the shock hits a job match.

The initial labor market equilibrium defines the overall levels of unemployment u , job creation, optimal working hours h , wages $\omega(h, \gamma)$, and the firing threshold $\tilde{\gamma}$. Note that the initial equilibrium is defined in the absence of disaster shocks, that is, at $\gamma = \underline{\gamma}$ and, hence, with the greatest possible productivity. Furthermore, firms can adjust the number of working hours instantaneously and without any constraint. In Appendix A, we derive the full equilibrium conditions and provide additional details.

2.1.2. Equilibrium under hours constraint and short-time work

To show how short-time work programs help labor markets reduce labor agreements' destruction in the face of an exogenous disaster shock, we show how increasing the generosity of short-time work mechanisms increases the model's endogenous firing threshold. An increase in this threshold means that the disaster shock must be more severe for a firm to destroy a job match or, equivalently, reduces the probability of

match destruction. Consequently, the impact that a natural disaster exerts on overall unemployment is smaller than in a scenario with less generous short-time work mechanisms.

In the new equilibrium, firms realize disaster shocks and decide whether or not to destroy job matches according to the firing threshold $\tilde{\gamma}$ defined in the initial equilibrium by setting $rJ(\tilde{\gamma}) = 0$. We assume that wages $\bar{\omega}$ remain as in the initial equilibrium. These are affected neither by the shocks nor by the short-time work policy. Furthermore, following Cooper et al. (2017), we assume that contractual working hours $\underline{h}$ impose a lower threshold to the optimal number of hours a firm can set, $h \geq \underline{h}$. These restrictions reflect a short-term scenario of wage rigidities and the absence of working time flexibility instruments typically enforced by employment protection laws.

Let us define a short-time work program as $\mathcal{STW} = \{\Xi, \xi_f, \xi_w\}$. The first policy component refers to the number of permissible hours reductions, with $0 < \Xi \leq \underline{h}$. While $\Xi = 0$ represents a case without a short-time work policy, $\Xi = \underline{h}$ represents the most generous case of full hours coverage. The other two components refer to the level of government wage compensation of non-worked hours received by firms and workers, respectively, with $0 < \xi_f, \xi_w \leq 1$. The upper end represents the maximum possible generosity level since employees and firms will receive a full salary compensation for non-worked hours.

The first policy component loosens the contractual hour constraint such that each firm is now allowed to set hours subject to $h \geq \underline{h} - \Xi$. Equation 1 gives the corresponding firm's decision on the number of optimal hours. According to it, a firm will choose the highest value from two options: the binding constraint given by $\underline{h}$ minus the number of permissible hour reductions and the optimal working hours from the initial equilibrium.

$$h^* = \max \left\{ \underline{h} - \Xi, \left[\frac{\Omega_h(h^*)}{\alpha(1 - \gamma)} \right]^{\frac{1}{\alpha-1}} \right\} \quad (1)$$

The value functions for workers and jobs are given by equations 2 and 3, respectively. According to the first, workers receive income from the new optimal number

228 of hours plus a share ξ_w of the difference between contractual and new optimal hours,
 229 that is, non-worked hours. $\Omega(h)$ stands for the dis-utility of labor and the last term
 230 in the equation is the worker surplus. Similarly, the new present discounted value of
 231 a job now depends on the new optimal number of hours plus a share ξ_f of the non-
 232 worked hours. The last term in the equation is the job surplus after using the free
 233 entry condition $V = 0$. Thus, the short-time work components ξ_w and ξ_f increase the
 234 value of jobs and employed persons in the economy.

$$rW(\gamma) = \bar{\omega} \cdot h + \bar{\omega} \cdot \xi_w(\underline{h} - h) - \Omega(h) + \lambda[E(W) + F(\tilde{\gamma})U - W(\gamma)] \quad (2)$$

$$rJ(\gamma) = (1 - \gamma) \cdot p(h) - \bar{\omega} \cdot \underline{h} + \bar{\omega} \cdot \xi_f(\underline{h} - h) + \lambda[E(J) - J(\gamma)] \quad (3)$$

235 By using the job value function and replacing h with the binding constraint $\underline{h} - \Xi$,
 236 equation 4 shows the new firing threshold as a function of short-time work instruments.
 237 Notably, as the generosity of the instruments ξ_f and Ξ increases, the firing threshold
 238 increases $[\tilde{\gamma}_i \geq 0 \quad \forall \quad i = \xi_f, \Xi]$. Figure 1 gives a visual representation of the right
 239 shift of the firing threshold.

$$\tilde{\gamma} = 1 - \frac{\bar{\omega}}{p(h)}(\underline{h} - \xi_f \Xi) + \frac{\lambda}{r + \lambda} \int_{\underline{\gamma}}^{\tilde{\gamma}} (\tilde{\gamma} - x) dF(x) \quad (4)$$

240 An increase of the firing threshold decreases the unemployment effect following
 241 a natural disaster, which is evident from the evolution of unemployed individuals
 242 $\dot{u} = \lambda F(\tilde{\gamma}) \cdot (1 - u) - \lambda_w \cdot u$, with λ_w standing for the rate of match creation and $F(\tilde{\gamma})$
 243 for the rate of match destruction. As $\tilde{\gamma}$ increases, $F(\tilde{\gamma})$ decreases, hence reducing the
 244 number of individuals entering unemployment.

Figure 1: Firing threshold and short-time work

Notes: This figure shows the distribution of natural disaster shock intensities and how the firing threshold shifts to the right due to short-time work.

2.2. The 2013 European floods

In May and June 2013, intense rainfall caused abnormal water levels across Central European river basins.⁹ Although the flood start and duration vary across countries, the first floods occurred in the second half of May and reached a maximum during the first week of June. Flooded areas included 1,800 municipalities in twelve federal states in Germany, seven states in Austria, 1,400 municipalities in ten provinces within the Czech Republic, the Bratislava – Devín region in Slovakia, and eight counties along the Danube valley in Hungary (ICPDR, 2014).¹⁰ The inundations also affected large urban centers including Dresden, Vienna, and Prague.

Although Germany had the most substantial direct losses (€ 8.2 billion), loss estimates in other countries also point to considerable damage: € 0.9 billion in Austria, € 0.6 billion in the Czech Republic, and € 0.03 billion in Hungary (European Commission, 2015). The administrative regions with the greatest financial losses were Saxony-Anhalt (40%), Saxony (29%), Bavaria (20%), and Thuringia (7%) in Germany (Thieken et al., 2016); Upper Austria (40%), Lower Austria (24%), Tyrol (23%), and

⁹The most affected river basins were the Danube, Elbe, Rhine, Wesser, Inn, Morava, Vltava, Ohre, Odra, Berounka, and their tributaries.

¹⁰Many of these regions declared a state of emergency, among them, eight states in Germany and six provinces in the Czech Republic. Further countries with minor damage include Croatia, Serbia, Romania, and Bulgaria.

Salzburg (10%) in Austria (European Commission, 2018); and Central Bohemia (27%), Prague (25%), Ústí nad Labem (23%), and South Bohemia (13%) in the Czech Republic (Czech Hydrometeorological Institute, 2014). Given the size of the losses, all of the aforementioned countries, except Hungary, received support from the European Union Solidarity Fund (EUSF) (European Commission, 2015). In Germany, the government launched flood-relief funds for around € 8 billion, and the insurance industry covered around € 1.65 billion (Thieken et al., 2016).

The flood caused infrastructure damages, including the transport, telecommunication, water, electricity, and gas networks. In Germany, reports reveal 250,000 hectares of flooded agricultural land and production disruptions in several prominent firms, including Porsche (Leipzig), Volkswagen (Zwickau), and Südzucker (Zeitz) (Khazai et al., 2013). Thieken et al. (2016) report that more than 32,000 residential buildings suffered damage and that around 19% of the direct losses corresponded to companies in the industrial and commercial sectors. The Czech Republic had 48,000 hectares of flooded agricultural land, 7,000 affected residential buildings, and about 16% of the direct costs accruing to businesses (Czech Hydrometeorological Institute, 2014). In Austria, 22,000 hectares of agricultural land remained underwater and over 300 firms were directly affected, while in Hungary, reports indicate 2,500 hectares of flooded farmland (European Commission, 2015).

2.3. Short-time work programs

Short-time work programs are employment subsidy mechanisms designed to prevent involuntary dismissals during periods of temporary business-downturn. Short-time working allowances are the corresponding transfers received by firms and paid to employees who benefit from temporary income support. Companies also benefit from the programs, as they retain core employees, avoid dismissal costs, and regain production levels without delay once the crisis is over. From a macro perspective, short-time work can slow the spiral of declining unemployment, wage deflation, and demand. Additionally, the psychological effect of being under the program rather than unemployed has a more substantial impact in supporting domestic demand than unemployment benefits (Crimmann et al., 2010).

290 However, like other subsidies, short-time work schemes are subject to several prob-
291 lems that reduce their cost-effectiveness (Hijzen and Venn, 2011). The two most
292 prominent are dead-weight losses and displacement costs. Dead-weight losses occur
293 when benefiting employees would anyway be regular-time employed in the absence of
294 short-time work. Displacement costs happen when the allowances preserve jobs that
295 would have been destroyed in the absence of the subsidy, hence locking workers into
296 low-productivity job matches. The consequences of the latter include the potential of
297 preventing creative destruction processes (Crespo Cuaresma et al., 2008; Leiter et al.,
298 2009) and impeding companies with strong growth potential to hire locked-in workers.
299 These problems become more dramatic when crises last for a long time (Brenke et al.,
300 2013).

301 Short-time work programs vary depending on generosity, work-sharing, eligibil-
302 ity, and conditionality requirements (Hijzen and Venn, 2011). These program design
303 features can account for differences in participation rates across different countries
304 (Boeri and Bruecker, 2011; Cahuc and Carcillo, 2011). Generosity refers to the cost
305 of implementation, such as the share covered by firms, worker’s perceived income,
306 and the maximum duration of the program. Concerning company requirements to
307 receive allowances, these include setting up the distribution of hour reductions among
308 workers, providing evidence of temporary business downturns, or training obligations.
309 Amendments to the regulatory framework, for instance, by making conditions more
310 attractive or speeding up implementation, aim at increasing participation rates during
311 periods of economic downturn. However, amendments imply a trade-off between take-
312 up and cost-effectiveness, which in periods of crisis usually shifts toward maximizing
313 participation (Hijzen and Venn, 2011). The shift occurs because dead-weight and dis-
314 placement costs are less significant during economic downturns (Boeri and Bruecker,
315 2011).

2.4. Short-time work programs in nations affected by the 2013 floods

Considering that previous cross-country studies on short-time work only provide information about the programs during the 2008 financial crisis, Table 1 presents some of the features of affected nations' short-time work programs in 2013.¹¹ With a long history of implementation, significant duration, and high levels of generosity, Germany and Austria had the most robust mechanisms across all five nations during the 2013 European floods. This is in line with Sacchi et al. (2011), who show that, compared to the Italian short-time work program, the program features in Germany and Austria share many similarities. In contrast, Hungary had no active program, while the Czech Republic and Slovakia had a significantly less generous and shorter in duration program.¹² Moreover, the Czech Republic and Slovakia, already less experienced with implementing these types of programs, did not modify their existing programs to encourage take-up during the catastrophe. According to Arpaia et al. (2010, p. 5), countries with less robust programs also imposed stricter conditions on the application process. We next take a closer look at some of these characteristics.

Germany was the first country to implement short-time work policies over a century ago (Messenger and Ghosheh, 2013). The German short-time work program or Kurzarbeit saw considerable participation rates particularly during both post-war periods, the Great Depression, the 1970s and 80s oil crises, German reunification, and throughout the 2008 financial crisis (Brenke et al., 2013). Economic short-time work applies if a company suffers from business downturns or unavoidable events. To qualify for the program, the employer must send a report to the Federal Employment Agency after reaching an agreement with its employees and after alternative work-reduction measures, such as the use of overtime hours, are exhausted. Essential conditions include the "one-third" rule, requiring that at least one-third of the company employees are affected by a loss of earnings of ten to hundred percent of their gross monthly

¹¹The German Social Security Code **SGB** III, the Austrian Labor Market Services Act (§37b), and the Slovak Employment Services Act (§50k) contain additional details on the programs.

¹²Hungary implemented three different programs during the financial crisis, the two nationally-financed schemes finished in 2009 and an ESF-financed project completed in early 2010 (OECD, 2010). There was no evidence of any active post-recession short-time work scheme in the country.

Table 1: Differences between short-time work programs in 2013

	Austria	Germany	Czechia	Hungary	Slovakia
Permissible reductions	10% - 90%	10% - 100%	20% - 60%	-	6% - 20%
Maximum duration (months)	24	24	12	-	3
Replacement rate	55%	60%	60%	-	60%
Compensation rate	55%	60%	N/D	-	30%
Compensation limit			✓	-	✓
Cost to employer	15%	10%	25%	-	50%
Initial job retention (paid by employer)			✓	-	✓
Program before 2008	✓	✓		-	
Program in 2013	✓	✓	✓	-	✓
Flood amendments	✓	✓		-	

Notes: This table compares program characteristics in different affected nations in 2013. Permissible reductions refer to the minimum and maximum reductions in weekly working hours. The maximum duration refers to the maximum number of months that an employee can receive the subsidy. The cost to the employer is the percentage of the wage covered by firms for hours not worked (we borrow 2008 values from Hijzen and Venn (2011)). Evidence refers to the requirement of showing evidence of a business downturn. Flood amendments refer to the existence of any amendment facilitating participation during the 2013 floods.

salary. Although the regular maximum duration of the subsidy is six months, it can be extended up to twenty-four months under exceptional circumstances. The subsidy amounts to sixty percent of the difference between the target and net wage.¹³ Companies also have to cover part of the costs of non-worked hours. For instance, they need to cover around eighty percent of employer's and employee's share of social security contributions of non-worked hours.¹⁴ During the 2013 floods, not only could directly affected companies receive the benefit, but also those indirectly affected.¹⁵ Under a € 15 million special program implemented between June and December 2013, 3,400 directly affected companies (and almost 18,000 employees) could get their social security contributions reimbursed for a maximum of three months (European Commission, 2013; BA, 2014). Furthermore, the Federal Employment Agency circulated an information sheet to companies affected by the flood, offering assistance and reporting simplifications to the application process (BA, 2013).

Austria implemented short-time work (Kurzarbeiterbeihilfe) for the first time dur-

¹³For a 100% loss of working time, the employee receives the same income as with unemployment benefits.

¹⁴These additional costs represented about 46% - 59% of usual labor costs for each working hour lost in 2008 (Brenke et al., 2013).

¹⁵A company is indirectly affected when it limits production because the supplying companies cannot deliver due to flooding.

ing the inter-war period of 1918-1939 (Suschitz, 2010). In 2013, employers whose activity was affected by temporary non-seasonal economic difficulties were eligible as long as they applied for assistance three weeks before the start of the program. The regular program's duration was between six and twenty-four months, requiring the loss of work to be between ten and ninety percent of the regular weekly working hours. Depending on the net remuneration level and irrespective of the number of working hours and associated loss, employees receive about ninety percent of their monthly salary. This program also saw considerable participation rates during previous disasters, such as the 2002 floods (Bock-Schappelwein et al., 2011). Furthermore, in the event of natural disasters, individual companies can bypass the requirement of having a collective agreement. Additionally, Austria employed several mechanisms to encourage participation during the floods. Through a public announcement, the authorities assured that the process was going to be handled "quickly and easily," as opposed to regular conventions (Niederösterreichische Nachrichten, 2013). The Labor Market Service in Tirol even launched a unique disaster-specific project under the title "Flood Disaster June 2013" (Tiroler Tageszeitung, 2013).

The Czech Republic implemented the program "Educate Yourself for Stability" (Vzdělávejte se pro stabilitu) between September 2012 and August 2015 (MLSACZ, 2012). The program received a total of CZK 400 million (around € 16 million in 2013) (85% ESF and 15% national) to enable employers to obtain a financial contribution for implementing professional development programs during periods of economic downturn, including support to the wage costs of trained employees. To be eligible, companies needed to show a decrease of more than twenty percent in the volume of sales per employee in three calendar months before applying compared with the equivalent period of the previous year. Additionally, they must show that they could not allocate work for more than twenty percent of the weekly working hours (up to a maximum of sixty percent). Besides this, they must provide evidence that, at their own expense, they retained jobs for at least one month before the application. Note that employers must pay a wage compensation of at least sixty percent of average earnings to affected employees throughout the whole downturn period. The government subsidy supports this wage compensation. The monthly allowance covered up to CZK 31,000 (around

388 € 1200 in 2013) of the wage compensation amount. The regular period of granting
389 the support was six months (up to twelve months).

390 Slovakia implemented the program "Contribution to Support the Maintenance of
391 Jobs" (Príspevok na podporu udržania pracovných miest) (UPSVR, 2012). This pro-
392 gram has many similarities to the one in the Czech Republic. To be eligible, employers
393 must give evidence of a transitional business downturn and pay a wage compensation
394 of at least sixty percent of average earnings to affected employees throughout that
395 period. However, stricter than in the Czech Republic, they must show that they re-
396 tained jobs at their own expense for at least three months before the application. The
397 monthly short-time work allowance was fifty percent of this wage compensation, up
398 to fifty percent of the country's average wage in the previous year (Slovakia's average
399 gross monthly wage was close to € 800 in 2012). The loss of work had to be between
400 six and twenty percent of the contractual weekly working hours. Employers could
401 implement the program for sixty working days, as long as the contractual relationship
402 started at least twelve months before the request.

403 Despite the existence of short-time work in Slovakia and the Czech Republic, we
404 could not find any information indicating its use or any amendment facilitating par-
405 ticipation during the floods. Besides the lack of crisis-specific modifications, their
406 programs' restrictive characteristics suggest that these countries did not have suit-
407 able mechanisms to reduce the disaster's adverse effects on their labor market. These
408 restrictive characteristics include budget constraints and low levels of generosity in
409 Slovakia or the training obligation and the "loss in the last three months" requirement
410 in the Czech Republic. Motivated by this, in Slovakia as of 2020, there is pressure to
411 shift to the German short-time work model. However, government officials claim that
412 the introduction of such a model would require extensive legislative changes that the
413 government does not foresee (MLSAF, 2020). Moreover, because participation rates
414 in the Czech Republic in 2013 were lower than expected, in 2014, the authorities made
415 several amendments to the program's features (LOCZ, 2014).

416 Figure 2 presents yearly series for the average number of reports and the total
417 number of workers under short-time work in Germany and Austria. Although Germany
418 discloses monthly data on a periodical basis, which we use later in the paper, we plot

yearly values for comparison reasons given that Austria only reports data with yearly frequency.¹⁶ The left panel shows values from 2007 to 2015; the right panel zooms in on the 2011-2015 period. Following the enormous increase in participation during the 2008 financial crisis, there is a downward sloping trend after 2009 in both nations. Despite this, we see that in 2013 there seems to be an unusual increase in the use of short-time work. For instance, Austria had 1,797 reports and a total of 4,010 short-time employees in 2013, corresponding to a year-to-year increase of 32% and 13%, respectively.

2.5. Other institutional arrangements and interaction

Two major national-level labor institutions affecting dismissals and, therefore, the demand for short-time work refer to employment protection legislation and the generosity of unemployment benefits (Van Audenrode, 1994; Boeri and Bruecker, 2011; Cahuc and Carcillo, 2011). Strict employment protection and less generous unemployment benefits are related to higher take-up rates during the 2008 financial crisis (Boeri and Bruecker, 2011; Cahuc and Carcillo, 2011). Employment protection raises the relative costs of layoffs, making work-sharing strategies more attractive. Stable employment during periods of economic downturn affecting labor demand means that employers could not layoff or voluntarily decided not to do so. Whereas the latter strategy refers to labor hoarding strategies, the former is closely related to the prevailing strictness of employment protection (Möller, 2010). The generosity of unemployment benefits, on the other hand, works in the opposite direction. Generous unemployment benefits, relative to the generosity of the short-time work compensation, make unemployment a superior income maintenance strategy. According to Van Audenrode (1994), to generate significant fluctuations in working hours, short-time work must be more generous than unemployment benefits. Note that under generous unemployment benefits but the absence of short-time work, firms would solely rely on unemployment insurance to finance dismissals, making the latter less efficient and imposing a greater negative fiscal externality (Arpaia et al., 2010; Boeri and Bruecker, 2011).

¹⁶Unfortunately, we could not find quantitative information regarding short-time work participation for other countries.

Figure 2: Short-time work participation in Austria and Germany (yearly values)

Notes: This figure shows short-time work participation in Austria and Germany. The left panel shows values from 2007 to 2015. To better visualize the shock in 2013, the right panel repeats the values from 2011 to 2015. For Austria, reports are the annual average of the number of monthly funding cases and workers are the total number of employees who received funding in the year (Nagl et al., 2019). For Germany, reports are the annual average number of monthly reports (economic short-time work) and workers are the total number of employees that appear in the reports in that year (BA, 2020). Note that the magnitudes between the two countries are not directly comparable since each person is counted once in Austria, and not all reports receive funding in Germany.

447 Table 2 presents values on the two institutions for each of the five inundated coun-
 448 tries. Regarding the strictness of employment protection, we see that although Aus-
 449 tria, Germany, and Slovakia have similar index values, the Czech Republic has a much
 450 stricter employment protection legislation. It stands in contrast to Hungary, which has
 451 a much lower index value. These values suggest that in the Czech Republic, layoffs are
 452 more expensive relative to other countries. To substitute for this, companies will try
 453 to use time-flexibility measures and apply for wage-support assistance programs. Con-

Table 2: Institutional interaction indicators in 2013

	Austria	Germany	Czechia	Hungary	Slovakia
Employment protection strictness	2.29	2.60	3.26	1.59	2.51
Generosity of unemployment benefits (percentage of previous income)	55%	59%	65%	68%	62%

Notes: This table reports values on the strictness of employment protection and the generosity of unemployment benefits for each inundated country. For the strictness of employment protection, we use the OECD index on individual and collective dismissals of regular contracts in 2013. For the generosity of unemployment benefits, we use the OECD net replacement rates in unemployment, which refer to the percentage of previous in-work income after two months of being unemployed in 2013.

cerning the generosity of unemployment, we see that while Austria and Germany have slightly lower values than the rest of the countries, Hungary has the most generous unemployment benefits. This means that employees in Hungary are, from an income perspective, better off going into unemployment than employees in other countries. Compared to short-time work replacement rates, we see that, while most countries have very similar values, the replacement rate of unemployment in the Czech Republic (Slovakia) is higher than that of short-time work by five (two) points. From an income perspective, employees might again prefer unemployment to short-time work. Altogether, it is possible to say the institutional setting in Hungary facilitates labor adjustments via the extensive margin by combining lenient employment protection with high unemployment benefits. Although unemployment benefits are also high in the Czech republic, employment protection makes short-run employment adjustments somewhat prohibitive.

3. Data and overview

Conforming to the floods' duration and different severity levels by region, we use monthly data at the county level for the analysis.¹⁷ For all variables, we work exclusively with information for years 2011 to 2015, which corresponds to the most

¹⁷To homogenize counties across nations, we work at the NUTS (Nomenclature of Territorial Units for Statistics) 3 level.

prolonged symmetric period around the flooded month (June 2013) not overlapping with the long-term effects of the financial crisis in 2008. Monthly data on short-time work and unemployment across all German counties comes from the Federal Employment Agency (BA, 2020).¹⁸ We consider three key participation variables: the number of short-time companies, the number of short-time employees, and the number of full-time equivalents (FTEs).¹⁹ Although the remaining countries do not disclose monthly short-time work data, we retrieve unemployment data from the Public Employment Service of Austria (AuM, 2020); the Ministry of Labour and Social Affairs of the Czech Republic (MLSACZ, 2020); the Ministry of Labor, Social Affairs and Family of the Slovak Republic (MLSAFSK, 2020); and the Hungarian Central Statistical Office (Hungarian Statistical Office, 2020).²⁰

To calculate the flood extent, we use inundation maps from NASA’s MODIS Near Real-Time Global Flood Mapping Project (Policelli et al., 2017). These maps are based on MODIS 250m resolution (10x10 degree tiles) data from NASA’s Terra and Aqua satellites. The project uses an algorithm that identifies flooded areas by comparing detected water to a reference water layer. To minimize shadow problems from clouds and terrain, it generates several multi-day composites of water surfaces. In this study, we use the 3-day composite product, which uses three consecutive days to determine the flood extent for one particular day. To get the maximum flood extent, we overlay all daily flood extents during the flood period (May 20th to June 30th).²¹

Figure 3 depicts affected counties according to three different flood extent groups: counties with less than one, one to five, and more than five square kilometers of flooded land.²² In line with information on the regions with the highest financial losses presented above, the most affected areas cluster along the Elbe river in Germany

¹⁸We only use data on economic short-time work since it is the only category covering unexpected events including natural disasters.

¹⁹The Federal Employment Agency calculates the latter based on the difference between target and actual remunerations.

²⁰Given that the Hungarian Central Statistical Office only discloses quarterly unemployment at the county level, we impute missing monthly values by using monthly national unemployment rates and quarterly regional shares of employment.

²¹Given that the algorithm generates several pixel edge errors along the coastline due to the use of a static reference water layer, we exclude inundations along the coast.

²²Inundation areas per region follow a very skewed distribution, with a mean (median) value of 4.87 (0.86) square kilometers and a standard deviation of 14.41.

495 (north-east of the country), the Danube river (close to the border between Austria,
 496 Slovakia, and Hungary and through central Hungary), the Ohre and Vltava rivers in
 497 the Czech Republic (west of the country), and the Rhine and Inn rivers in Austria
 498 (west of the country). With almost 200 square kilometers of flooded land, Stendal is
 499 the (German) county with the greatest extent of flooding. Table 3 presents further
 500 descriptive information on the inundations. With 1,424 square kilometers of flooded
 501 land, the inundations affected 61% of all counties: 227 in Germany, 30 in Austria, 14
 502 in the Czech Republic, 15 in Hungary, and 7 in Slovakia. Note, however, that although
 503 Germany has the highest number of affected counties, the flood only affects 57% of its
 504 counties, while affecting all counties of the Czech Republic.

Figure 3: The 2013 Central European floods by county and flood extent

Geo-source: Policelli et al. (2017)

Notes: This map shows flood-affected counties (NUTS 3 regions) in the five affected nations according to three flood extent levels. To calculate flooded areas in km^2 for each county, we sum up all inundations (in white) within each county. The main river network is in blue.

Table 3: Flooded regions by flood extent and country

	Number of affected counties	% of all counties in the country	Total flooded area (km^2)	% of total area of affected counties
Counties with reported high-water levels				
Germany	227	56.61	1059	0.42
Austria	30	85.71	155	0.21
Czechia	14	100	44	0.06
Hungary	15	75.00	148	0.23
Slovakia	7	87.50	19	0.05
Total	293	61.30	1426	0.28

Notes: For each flood-affected nation, this table presents the number and percentage of affected counties and corresponding flooded area in km^2 .

Figure 4 plots the temporal variation of the three variables measuring short-time work in Germany. From the left panel, we see that, at the monthly level, short-time work is higher during the first months of the year and lower in the summer months and December. Concerning yearly behavior, short-time work decreases throughout the sample period, with its highest value in 2011 and its lowest in 2015, in line with the yearly country-level figures presented above. This long-term behavior comes from the German busyness cycle and its recovery after the 2008 financial crisis. To have a better look at the behavior of the variables during the flood, Table 4 presents the May-to-June growth rates in 2012, 2013, and 2014. The first row in each panel shows the value for all counties in the country, the next only for flooded counties, and the third for Stendal, the most flooded county. While, in line with the average monthly variation, changes in 2012 and 2014 are generally negative and always small; in 2013, they are positive and larger in magnitude. As expected, the effects become larger when we only include flooded counties, and they become enormous for Stendal, with growth values over 4,000% in the number of FTEs.²³

Finally, Figure 5 presents monthly and yearly variation in regional unemployment rates across affected Central European countries. On average, regional unemployment rates are higher in Slovakia and lower for Austria and Germany. All nations exhibit a u-shaped monthly behavior with valleys in the summer and peaks during the winter, notably Austria and the Czech Republic. Concerning the long-term behavior, we can see a negative trend in Germany, Hungary, and the Czech Republic. In Slovakia, unemployment increases until 2013 and drops sharply thereafter, while in Austria, we

²³The results keep increasing in size as we increase the flood threshold to consider a county as inundated.

Figure 4: Temporal variation in regional short-time work in Germany

Notes: The figure shows the temporal variation in average regional short-time work participation for each month of the year (left panel) and each year of the sample period (right panel). The y-axis gives the percentage deviation from the overall average. For example, a value of zero means that for that month (year), short-time work is the same as the average over all months (years).

Table 4: May-to-June regional short-time work participation growth rates in Germany

	May-to-June growth		
	2012	2013	2014
Short-time companies			
All counties	-7.76%	24.25%	-11.96%
Flooded counties	-5.49%	41.52%	-13.07%
Stendal	-14.29%	2100.00%	0.00%
Short-time employees			
All counties	-10.26%	16.73%	-7.76 %
Flooded counties	-6.77%	21.38%	-6.70%
Stendal	3.85%	1844.83%	0.00%
FTEs			
All counties	-9.76%	28.36%	-19.69%
Flooded counties	-5.52%	35.75%	-8.35%
Stendal	49.06%	4465.81%	0.00%

Notes: This table presents May-to-June growth rates of short-time companies (upper panel), employees (middle panel), and FTEs (lower panel) in 2012, 2013, and 2014, for different groups of counties. Except for the district of Stendal, values are regional averages over all counties in a given group.

527 can see a stable increase between 2011 and 2015.

Figure 5: Temporal variation in regional unemployment

Notes: This figure shows the temporal variation in average regional unemployment rates for the Central European countries affected by the 2013 European floods. The left panel shows the month to month averages and the right panel the yearly means.

4. Empirical strategy

To determine if short-time work programs are effective in avoiding unemployment after a natural disaster, we first provide empirical evidence on the use of short-time work in Germany and the stability of employment in Germany and Austria during the floods. If the floods have an impact, we would expect to see a significant increase in all short-time work variables. Although data limitations prevent us from conducting this exercise for other nations, we expect these to have lower participation rates considering that the restrictive characteristics of the programs limit participation (Boeri and Bruecker, 2011; Cahuc and Carcillo, 2011). Further, given the robust characteristics of programs in Germany and Austria, we expect to find little to no monthly unemployment effects.

Could Germany and Austria have experienced no unemployment changes even in the absence of a robust short-time work program? To see if short-time work is related to previous labor market outcomes, we exploit the variation in short-time work program characteristics in other flooded nations and flood extent intensities. Although we would ideally compare flooded regions in Germany and Austria with other same countries' flooded regions without (sufficient) access to short-time work, the country-wide coverage of the programs does not allow us to construct such a counterfactual.

To substitute for that, we refer to labor market outcomes in the three other affected nations. Although these countries show high variability in their programs, all had more restrictive characteristics. Based on previous studies giving evidence on lower short-time participation rates in countries with less robust programs and on the adverse effects of natural disasters in labor markets, we expect to find (larger) positive changes in unemployment in countries with such programs compared to countries with robust programs. To strengthen the previous argument, we exploit the differences in flood intensities by stepwise restricting the sample to regions with a larger flooded area. As we reduce the sample, we expect to find higher short-time work participation in Germany along with no unemployment changes in countries with robust programs, but more substantial employment effects in the other countries.

To avoid contaminated point estimates arising from unaccounted temporal effects, we run an augmented local-linear regression discontinuity in time design (ARDiT) (Hausman and Rapson, 2018).²⁴ The ARDiT framework divides the estimation into two stages. In the first stage, we control for temporal covariates by running a fixed-effects panel regression of our dependent variables as a function of time effects. In the second stage, we use the residuals from the first stage in a standard local-linear regression discontinuity design.^{25,26} As such, the ARDiT design captures the local average treatment effect of the inundations on our dependent variables.

Equation 5 shows the first stage regression. In line with studies on the growth effects of natural disasters, $\Delta \ln y_{ct}^i$ is the first log-difference $[\ln(y_{ct}^i) - \ln(y_{ct-1}^i)]$ of variable i at time t in county c . $\ln y_{ct-1}^i$ is the lagged natural logarithm of y_{ct}^i , ω_t controls for the year of the observation, v_t for the month, γ_c is a term of county-specific fixed effects, and μ_{ct}^i are the residuals.²⁷ The dependent variable i is the growth rate of the number of short-time firms, the number of short-time employees, the number of FTEs, and the unemployment rate in county c and month-year t . Due to information limitations, we only run the first three variables for Germany.

²⁴For instance, if May and June are months with high levels of unemployment, failing to control for the month effect would increase the coefficients of a simple regression discontinuity design.

²⁵Gelman and Imbens (2019) provide evidence on the better performance of local linear fits versus higher-order polynomials of the running variable in regression discontinuity designs.

²⁶For all regressions, we use the R package 'rdrobust' (Calonico et al., 2015).

²⁷Studies using the same first log-difference growth specification include Felbermayr and Gröschl (2014) or Loayza et al. (2012).

$$\Delta \ln y_{ct}^i = \rho_i \ln y_{ct-1}^i + \omega_t + v_t + \gamma_c + \mu_{ct}^i \quad (5)$$

Equation 6 specifies the functional form of the second stage. μ_{st}^i are the residuals from the previous equation. $Flood_{ct}$ is a dummy variable that equals one after the flood and zero otherwise. β_i is the point estimate of interest as it measures the impact of the flood at the discontinuity. x_{ct} is a running variable measuring the temporal distance to the discontinuity date. $f(Flood_{ct} \times x_{ct})$ is a linear trend before and after the discontinuity, and ϵ_{ct} is an idiosyncratic error term. Because the floods began in May 2013, and companies were not able to receive benefits until June, we set the discontinuity for the short-time work variables to June and for the unemployment rates to May. Finally, we cluster standard errors at the month $\times$ county level.

$$\mu_{ct}^i = \beta_i Flood_{ct} + f(Flood_{ct} \cdot x_{ct}) + \epsilon_{ct}^i \quad (6)$$

We report results using robust-bias-corrected (RBC) confidence intervals. RBC differs from conventional OLS confidence intervals in that they take into consideration the bias stemming from the non-parametric approximation of the local polynomial in the determination of point estimates and standard errors at the discontinuity. According to Cattaneo et al. (2019), these estimates are theoretically valid, enjoy excellent optimality properties, and perform well in empirical applications. Additionally, we report observations to the left and right of the discontinuity, the bandwidth around the threshold, and the polynomials for both the estimate fit and its bias correction. The bandwidth around the discontinuity comes from the plug-in rules based on mean square error expansions described by Calonico et al. (2015).

The basis for identification is the idea that the floods are the only reason behind changes in our dependent variables at the date of the discontinuity. The only threat to identification is that conditional on year, month, and county fixed effects, there might still be uncontrolled and discontinuous time effects on the month of the floods. However, we do not find evidence of other relevant shocks occurring in the same counties and dates of the 2013 events. To test the robustness of the results, we also conduct placebo tests that randomize the discontinuity across space and time.

5. Results

5.1. Short-time work in Germany

Figure 6 shows the discontinuity in the residuals of short-time work participation variables in Germany's flooded counties. All three variables exhibit a clear spike in June 2013, the month of the inundation. This finding is remarkable given that June is traditionally a month with low levels of short-time work. Table 5 contains the estimation results at the discontinuity. We see a significant increase in the number of short-time companies by 29%, short-time employees by 25%, and full-time work equivalents by 33%. The endogenously estimated bandwidth revolves between three and ten months. It is in concordance with the maximum duration of the special flood program covering social security contributions of directly affected companies and the regular duration of short-time work.

Figure 6: Discontinuity of short-time work residuals in Germany

Notes: This figure contains the graphical representation of the discontinuity at $t = 0$ (June 2013) of the average residuals from the first difference of short-time-work variables (Equation 5). The red marks correspond to June 2011, 2012, 2013, 2014, and 2015. The global polynomial is of order 3 and uniform kernel.

5.2. Unemployment in flooded nations

Figure 7 shows the discontinuity in the unemployment residuals in flooded counties in Germany and Austria. Unlike the previous figures, there is a small negative spike for

Table 5: Regression discontinuity results for short-time work participation in Germany

<i>Discontinuity: 2013 European Floods</i>			
	$\Delta \ln$ Companies	$\Delta \ln$ Employees	$\Delta \ln$ FTEs
Robust Bias Corrected (RBC)	0.29*** (0.05)	0.25** (0.08)	0.33*** (0.07)
Obs. to the Left	669	894	894
Obs. to the Right	881	1101	1101
Conventional Est. Bandwidth	3.85	4.74	4.41
Bias-Corrected Est. Bandwidth	10.77	8.64	9.75

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; this table contains the results from the augmented local linear regression discontinuity design on the average number of short-time companies, short-time workers, and full-time work equivalents in the German counties affected by the 2013 European floods. The discontinuity month is June 2013. Standard errors are clustered at the county $\times$ month level. The order of the local-polynomial to construct the estimator (bias-correction) is 1 (2). The kernel function is triangular.

613 Austria and no spikes for Germany at the discontinuity. Table 6 shows the coefficients
614 of the ARDiT specification. As suggested by the figures, the point estimate exhibits a
615 non-significant negative effect in Austria while showing a significant marginal decrease
616 of one percent in Germany. This counter-intuitive reduction in unemployment after
617 the flood might be related to dead-weight losses in the implementation of short-time
618 work.²⁸

Table 6: Regression discontinuity results for unemployment in Austria and Germany

<i>Discontinuity: 2013 European Floods</i>		
	Austria $\Delta \ln$ Unemployment	Germany $\Delta \ln$ Unemployment
Robust Bias Corrected (RBC)	-0.09 (0.09)	-0.01** (0.00)
Obs. to the Left	150	2043
Obs. to the Right	180	2270
Conventional Est. Bandwidth	5.62	9.32
Bias-Corrected Est. Bandwidth	9.77	15.03

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. This table contains the results from the augmented local linear regression discontinuity design on the rates of unemployment for Austria and Germany. The discontinuity month is May 2013. Standard errors are clustered at the county $\times$ month level. The order of the local-polynomial to construct the estimator (bias-correction) is 1 (2). The kernel function is triangular.

²⁸As noted in the introduction and in line with this finding, Germany's unemployment rate also declined during the 2008 financial crisis (Messenger and Ghosheh, 2013).

Figure 7: Discontinuity of unemployment residuals in Austria and Germany

Notes: This figure contains the graphical representation of the discontinuity at $t = 0$ (May 2013) of the average residuals from the first difference of unemployment (Equation 5). The red marks correspond to June 2011, 2012, 2013, 2014, and 2015, except for Austria, for which we do not have data for 2011. The global polynomial is of order 3 and uniform kernel.

Figure 8 shows the discontinuity in the unemployment residuals in flooded counties of the other affected nations. In all cases, we can visually distinguish positive spikes at the discontinuity in the month of the flood, albeit smaller in magnitude compared to short-time participation variables. Table 7 shows the point estimates of the ARDiT design. All three countries show a significant increment after the floods. For the Czech Republic, Hungary, and Slovakia, the estimate indicates that the flood increased unemployment by 7%, 9%, and 6%, respectively. These results are insightful in that the unemployment rate of nations with less robust and generous short-time work schemes increases in the aftermath of the flood. That the most substantial effect is for Hungary is not surprising, given the absence of any short-time work program in this country.

5.3. Different flood extent intensities

Table 8 extends the previous results for different flood extent intensities: counties with more than one and more than five square kilometers of flooded land. From the first three columns, we see that all short-time work estimates grow significantly with the size of the affectation. For the number of short-time companies, employees, and FTEs, moving from all flooded counties to counties with more than five square kilometers of

Figure 8: Discontinuity of unemployment residuals in other flooded nations

Notes: This figure contains the graphical representation of the discontinuity at $t = 0$ (May 2013) of the average residuals from the first difference of unemployment (Equation 5). The red marks correspond to June 2011, 2012, 2013, 2014, and 2015. The global polynomial is of order 3 and uniform kernel.

Table 7: Regression discontinuity results for unemployment in other flooded nations

<i>Discontinuity: 2013 European Floods (May 2013)</i>			
	The Czech Republic $\Delta \ln$ Unemployment	Hungary $\Delta \ln$ Unemployment	Slovakia $\Delta \ln$ Unemployment
Robust Bias Corrected (RBC)	0.07*** (0.02)	0.09* (0.04)	0.06*** (0.02)
Obs. to the Left	42	75	42
Obs. to the Right	56	90	49
Conventional Est. Bandwidth	3.60	5.73	6.02
Bias-Corrected Est. Bandwidth	6.22	10.19	8.69

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. This table contains the results from the augmented local linear regression discontinuity design on the rate of unemployment for the Czech Republic, Hungary, and Slovakia. The discontinuity month is May 2013. Standard errors are clustered at the county $\times$ month level. The order of the local-polynomial to construct the estimator (bias-correction) is 1 (2). The kernel function is triangular.

635 flooded land, increases point estimates by 46%, 51%, and 43%, respectively. Regarding
636 unemployment, from columns four and five, we see that, while the coefficient does not
637 change for Germany, it slightly (negatively) grows for Austria but lacks significance
638 throughout the inundation intensities. The last three columns give the results for the
639 other nations. In line with our expectations, we see that unemployment increases with

the size of the inundation. Considering only significant coefficients, we see that, when moving from all flooded counties to counties with more than five square kilometers of flooded land, the Czech Republic and Hungary undergo unemployment increases of 7% and 8%, respectively. In Slovakia, unemployment increases by 3% at the one square kilometer threshold.

Table 8: Regression discontinuity results for different flood extent intensities

	<i>Discontinuity: 2013 European Floods</i>							
	$\Delta \ln$			$\Delta \ln$ Unemployment				
	Companies	Employees	FTEs	Austria	Germany	Czechia	Hungary	Slovakia
RBC (All)	0.29*** (0.05)	0.25** (0.08)	0.33*** (0.07)	-0.09 (0.09)	-0.01** (0.00)	0.07*** (0.02)	0.09* (0.04)	0.06*** (0.02)
RBC(1km ²)	0.40*** (0.08)	0.39** (0.13)	0.46*** (0.12)	-0.13 (0.10)	-0.01** (0.00)	0.10*** (0.02)	0.11* (0.05)	0.09*** (0.03)
RBC(5km ²)	0.75*** (0.15)	0.76*** (0.19)	0.76*** (0.17)	-0.13 (0.11)	-0.01* (0.01)	0.14* (0.07)	0.17* (0.07)	0.14 (0.11)

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$; this table contains the results from the augmented local linear regression discontinuity design on short-time work and unemployment variables in counties affected by the 2013 European floods. Standard errors are clustered at the county $\times$ month level. RBC stands for robust-bias-corrected estimates. In parenthesis, the minimum flooded area required to include a county in the regression.

5.4. Robustness

We test the robustness of our results by shifting the floods to Finland, Scotland, and the United Kingdom, countries that were utterly unaffected by the 2013 European floods.^{29,30} If the design is robust, we should not capture any impact at the discontinuity in these nation's unemployment rate. Table B.1 shows the estimation results. As expected, the point estimates are small and not significant for Finland and Scotland. Although the coefficient is significant in the UK-EWNI block, it is negative and small in magnitude.

²⁹The estimates for the United Kingdom refer to England, Wales, and Northern Ireland.

³⁰Monthly unemployment data for counties in Finland comes from the Employment Service Statistics of the Ministry of Economic Affairs and Employment (MEAE, 2020). Quarterly unemployment data for counties in the UK comes from the Annual Population Survey by the Office for National Statistics (ONS, 2020).

6. Conclusions

Based on evidence indicating that employment falls in the immediate aftermath of a natural disaster and on studies highlighting the effectiveness of short-time work programs in retaining jobs during the 2008 financial crisis, in this paper, we investigate the efficacy of short-time work to stabilize employment during the 2013 European floods. The empirical strategy uses regression discontinuity designs and exploits differences in the institutional background of affected nations to understand the dampening ability of short-time work programs. The model uses the sharp discontinuity in the flooded month to compare the value of variables just before and after the event.

Better than during the 2008 financial crisis, our results show that the short-time work mechanism could completely stabilize employment in flood-affected regions, in line with the literature that this mechanism reaches its maximum efficiency during short-lived shocks. We find high participation rates in Germany's flood-stricken regions and no unemployment changes in countries with robust short-time work programs (Germany and Austria), while uncovering increments in nations with less robust mechanisms. Specifically, regional unemployment rates in flooded regions of the Czech Republic, Hungary, and Slovakia increase by 7%, 9%, and 6%, respectively. As we reduce the sample only to include regions with a larger flooded area, we find that Germany's short-time work participation increases further, with unemployment remaining unaffected in Germany and Austria, but further increasing in the other flooded countries. Although the effects might point to different labor market mechanisms in each of the countries, we contend that, given that the impact happens simultaneously in many countries, it can be attributed to weaknesses or the absence of programs.

In a globalized world threatened with uncertainties of uncountable types, a better understanding of labor market programs' effectiveness is essential for ensuring economic well-being. The findings in this work are of interest for countries considering the implementation or adaptation of similar policies to cope with disasters' consequences. However, this does not mean that the German and Austrian programs can have the same effects in other contexts. As also argued by Boeri and Bruecker (2011), the success of such a program hinges upon other labor market institutions and their

interactions. Note also that, even if the short-time work mechanism was effective during the floods, we could not say anything about its cost-efficiency. It might be that, although the program could stabilize employment in flood-affected regions, the number of subsidized hours was inefficient. In the case of dead-weight losses, programs might include experience-rating components.

Further analyses, similar to those studying the 2008 financial crisis, could combine plant-level data with flood extent and land-use information, to study the determinants of the short-time work take-up decision at the firm and regional levels. Further opportunities include studying the behavior of additional labor market indicators, such as wages, or analyzing how the program affects the economy in the long run, for instance, by preventing creative destruction processes.

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A Appendix: Initial labor market equilibrium

In the model, the creation of matches $m(u, v)$ depends on a traditional Cobb-Douglas constant returns to scale matching function on the vacancy rate v and the unemployment rate u . The flow probability of matches for the job seeker and the company are equivalent to $\lambda_w = m(u, v)/u = \theta q(\theta)$ and $\lambda_f = m(u, v)/v = q(\theta)$, where θ is the parameter of market tightness (fraction of vacancies over unemployed persons $\theta = v/u$). The time evolution of unemployed persons in the economy is given by $\dot{u} = \lambda F(\underline{\gamma}) \cdot (1 - u) - \lambda_w \cdot u$, with existing matches endogenously separating at rate $\lambda F(\underline{\gamma})$, and new associations happening at rate λ_w . Equation A.1 shows the steady state version of the equation. Note how disaster shocks shift the Beveridge curve outward.

$$u = \frac{\lambda F(\underline{\gamma})}{\lambda F(\underline{\gamma}) + \lambda_w} \quad (\text{A.1})$$

Equation A.2 shows the present discounted value of a job, which depends on productivity, total wage paid $\omega(h, \gamma) \cdot h$, and the job's surplus depending on the expected job value $E(J) = \int_{\underline{\gamma}}^{\tilde{\gamma}} J(x) dF(x)$. r stands for the exogenous real interest rate. Note that the job's value depends on the disaster shock γ , which directly affects productivity: the larger the value of γ , the lower the firm's value. Equation A.3 shows the first-order-condition (FOC) of this equation concerning the intensive margin of labor demand (h). This equation shows that the firm chooses the optimal number of labor-hours by subtracting from the marginal increase in productivity the marginal cost of paying this extra hour to the matched employee.

$$rJ(\gamma) = (1 - \gamma) \cdot p(h) - \omega(h, \gamma) \cdot h + \lambda[E(J) - J(\gamma)] \quad (\text{A.2})$$

$$(1 - \gamma) \cdot p_h(h) - \omega_h(h, \gamma) \cdot h - \omega(h, \gamma) = 0 \quad (\text{A.3})$$

Equation A.4 shows the present discounted value of an unmatched firm (vacancy), where c is the cost of actively looking for a worker, and $\lambda_f(J(\gamma) - V)$ the probability of finding a match multiplied by the job's surplus. A company will keep its job offer open as long as $rV \geq 0$. Contrary, the firm will close and leave the matching pool.

$$rV = -c + \lambda_f(J(\underline{\gamma}) - V) \quad (\text{A.4})$$

Equations A.5 and A.6 show the value functions for employed and unemployed persons. The present discounted value of an employed person depends on the wage $\omega(h, \gamma)$, the number of working hours h , the disutility of labor $\Omega(h)$, and the worker's surplus depending on the expected value of being employed $E(W) = \int_{\underline{\gamma}}^{\tilde{\gamma}} W(x) dF(x)$. For the unemployed person, the value function depends on its income from unemployment benefits b , and the worker's surplus times the job-finding probability rate.

$$rW(\gamma) = \omega(h, \gamma) \cdot h - \Omega(h) + \lambda[E(W) + F(\underline{\gamma})U - W(\gamma)] \quad (\text{A.5})$$

$$rU = b + \lambda_w(W(\underline{\gamma}) - U) \quad (\text{A.6})$$

Traditionally, search and matching literature settles salaries with a straightforward Nash bargaining rule. This rule emerges because both firms and workers create bilateral monopolies by bargaining over the match quasi-rents. Equation A.7 shows the bargaining rule, where individuals and firms share the surplus from matching according to the worker's bargaining power β .

$$(1 - \beta)(W(\gamma) - U) = \beta(J(\gamma) - V) \quad (\text{A.7})$$

By substituting in this equation the previous value functions and using the free-

entry conditions requiring that $V = 0$, we obtain wage-setting equation A.8. Note that as γ increases, wages fall. According to this equation, when the disaster causes a productivity shock, the worker would earn a new wage $\omega^\gamma < \omega$. The reduction from ω to ω^γ entails match destruction because, for a share of workers, the outside option is now more attractive. Moreover, for firms unable to reduce wages due to wage rigidities, the only option is to destroy labor agreements.

$$\omega(h, \gamma) \cdot h = \beta[(1 - \gamma) \cdot p(h) + \theta c] + (1 - \beta)(b + \Omega(h)) \quad (\text{A.8})$$

Equation A.9 shows the optimal level of hours, after substituting the wage equation on the first-order condition of the firm's value function regarding working hours (Eq. A.3) and assuming that $p(h) = h^\alpha$ with $0 < \alpha < 1$. Note that the intensive margin of labor also depends on the disaster shock: the greater the shock, the lower the number of optimal hours $h_\gamma^* < 0$.

$$h^* = \left[\frac{\Omega_h(h)}{\alpha(1 - \gamma)} \right]^{\frac{1}{\alpha-1}} \quad (\text{A.9})$$

To derive the equilibrium values for job creation and the firing threshold, we plug in the equilibrium wage in the job value function, compute $J(\gamma) - J(\tilde{\gamma}) = 0$, use the free-entry condition $V = 0$ and the job destruction condition $J(\tilde{\gamma}) = 0$, and evaluate the expressions at $\gamma = \underline{\gamma}$. Equations A.10 and A.11 give the resulting conditions. Together, equations A.1, A.8, A.9, A.10, and A.11 characterize the labor market equilibrium.

$$\frac{(1 - \beta)}{r + \lambda}(\tilde{\gamma} - \underline{\gamma})p(h) = \frac{c}{\lambda_f} \quad (\text{A.10})$$

$$\tilde{\gamma} = 1 - \frac{1}{p(h)}(b + \Omega(h) + \frac{\beta}{1 - \beta}\theta c) + \frac{\lambda}{r + \lambda} \int_{\underline{\gamma}}^{\tilde{\gamma}} (\tilde{\gamma} - x) dF(x) \quad (\text{A.11})$$

B Appendix: Results from placebo trials

Table B.1: Regression discontinuity results for unemployment in unaffected nations

	<i>Discontinuity: 2013 European Floods</i>		
	Finland $\Delta \ln$ Unemployment	UK-EWNI $\Delta \ln$ Unemployment	Scotland $\Delta \ln$ Unemployment
Robust Bias Corrected (RBC)	0.01 (0.01)	-0.02*** (0.01)	0.06 (0.04)
Obs. to the Left	152	333	64
Obs. to the Right	171	444	87
Conventional Est. Bandwidth	8.86	3.26	3.18
Bias-Corrected Est. Bandwidth	13.24	5.40	5.57

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. This table contains the results from the augmented local linear regression discontinuity design on the rate of unemployment for Finland, UK-EWNI (England, Wales, and Northern Ireland), and Scotland. The discontinuity month is May 2013 for Finland and June 2013 for UK-EWNI and Scotland due to data limitations (quarterly unemployment). Standard errors are clustered at the county $\times$ month level. The order of the local-polynomial to construct the estimator (bias-correction) is 1 (2). The kernel function is triangular.