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When Weather Wounds Workers: The Impact of Temperature on Workplace Accidents*

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Abstract

We study the effects of temperature on occupational health using administrative data on Swiss occupational accidents from 1996 to 2019. Our results imply that on hot days ($T_{max} \geq 30°C$) the number of occupational accidents increases by 7.4% and on ice days ($T_{max} < 0°C$) by 6.3%, relative to mild days. We find that extreme temperatures cause an average of 2,600 workplace accidents each year, accounting for 1% of annual accidents. We provide suggestive evidence for insufficient sleep on hot days as a mechanism. While extreme temperatures worsen occupational health, we observe limited labor supply adaption for most workers.

Keywords: Occupational Health, Labor Supply, Climate Change
JEL Codes: I1, J2, Q5

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1 Introduction

The European Agency for Safety and Health (EU-OSHA) estimates that work-related accidents and illnesses result in the loss of 3.9% of all working years globally, equivalent to a cost of approximately EUR 2,680 billion. In the European Union alone, these costs amount to EUR 476 billion (EU-OSHA, 2017).[1] In 2019, 37% of establishments questioned in the European Survey of Enterprises on New and Emerging Risks cited heat, cold, or draughts as one of the major work-related risk factors (EU-OSHA, 2019). From the worker‘s perspective, 23% of employees questioned in the 2015 European Working Conditions Survey indicated that they are exposed to high temperatures at least 1/4 of the time, with significant sector-related heterogeneity (Eurofound, 2015).[2] At the same time, global warming in response to greenhouse gas emissions will continue throughout the century (IPCC, 2021), further increasing the risk of exposure to extreme temperatures in the workplace (Andrews et al., 2018).

This paper examines the impact of temperature on occupational safety using a unique high-resolution panel data set on the universe of registered occupational accidents in Switzerland from 1996 to 2019. For each workplace accident, we have the date and location, as well as detailed information on the demographic and socioeconomic characteristics of the injured party and the cause and consequences of the accident. We match more than 6 million accident insurance claims and daily information on temperature, precipitation, solar radiation, and wind speed using readings from Swiss weather stations distributed throughout the country. Using fixed effect Poisson regression, in which we control for a variety of concurrent environmental factors, we exploit plausibly exogenous daily variation in temperature over time within zip codes to characterize the causal relationship between temperatures and workplace accidents.

We find a pronounced increase in the number of workplace accidents on days when temperatures are at either end of the temperature distribution. The number of reported workplace accidents is 6.3 and 7.4 percent higher on days with maximum temperatures below 0°C and at least 30°C, respectively, than on mid-temperature days. Back-of-the-envelope cost calculations imply that an additional 62,400 temperature-related accidents occurred during

[1]See https://visualisation.osha.europa.eu/osh-costs for more information on the methodology used to derive these estimates and a breakdown of the costs by illness and region.

[2]For example, 38% of employees working in the construction and transport sector report that they are exposed to high temperatures. On the other hand, only 14% of European workers employed in financial and other service sectors indicate exposure to hot temperatures. Results of the survey exhibit the same pattern for exposure to cold temperatures.

the observation period resulting in total costs of close to CHF 2,200 million.[3] We estimate that under a worst-case emissions scenario with no mitigation measures implemented (RCP8.5), annual costs associated with temperature-related occupational accidents will increase by nearly 80% by the end of the century, from the current CHF 91 million to CHF 163 million. Heterogeneity analysis reveals that there are no differences in the impact of hot days on workplace accidents between gender, age, income, nationality, or industry. On ice days, however, the increase in the number of occupational accidents is most pronounced for high income and older workers, as well as for workers in low-weather-exposed industries. We find that the effect of ice days is also more pronounced for severe relative to non-severe accidents. We test indirectly for possible adaptation and find no evidence of adaptation to temperature extremes. The effects of extreme temperatures on occupational accidents are robust to different specifications and supported by placebo checks in which we randomly distribute extreme temperatures across time and space.

To investigate health-related mechanisms and labor supply adaption, we additionally draw on two representative survey data sets. We use information from around 90,000 Swiss Health Survey (SHS) interviews from 1992 to 2017 to examine potential changes in health outcomes due to temperature exposure that might act as a mechanism underlying the relationship between temperature and occupational accidents. The SHS is a survey on health status and health-related behavior, including questions on insomnia, loss of energy, concentration and alcohol consumption, and is conducted every five years. Our results suggest that insomnia on hot days is a potential mechanism behind our results. We find that the probability to report insomnia in the last 14 days increases by 0.7 p.p. for each additional hot day, which constitutes a 1% increase over the baseline probability of 70%. The results further indicate that high nighttime temperatures, and thus insomnia, are relatively more important for workplace accidents for workers with low-weather exposure than for workers with high-weather exposure. Next, we use data from around 420,000 interviews from the Swiss Labour Force Survey (SLFS) from 2010 to 2019, which provide individual-level information on weekly hours worked, to examine whether workers adjust their labor supply in response to extreme temperatures. The SLFS is a quarterly survey on the structure of the labor force and employment behavior. We document a non-linear relationship between temperatures and time allocated to labor for the overall sample. The results suggest that labor supply on net is rather unresponsive to temperatures. However, we find evidence of substantial differences by workplace weather exposure. Workers in low-exposure industries do not adjust their labor supply on days with cold temperatures and only slightly reduce their work hours by 0.17

[3] 1 CHF $\approx$ 1 USD in 2019 (OECD, 2023).

hours or 10 minutes on hot days. Workers in high-weather-exposed industries react to both ice and hot days, with an additional hot day reducing their weekly hours worked by 0.31 hours, or 19 minutes, suggesting that their labor supply response to hot temperatures is nearly twice as large.

Switzerland provides an interesting setting to study the causal impact of exposure to temperature extremes on occupational safety and health, labor supply, and the long run impact of climate change on occupational safety for several reasons. First, due to its unique geographical location the weather in Switzerland is characterized by large temporal and spatial variation, allowing us to study the effects over a broad temperature range. Second, Switzerland has been disproportionately affected by climate change, with a rise in average temperature by nearly 2°C between 1864 and 2017, compared to a global increase by 0.9°C, a pattern which is likely to persist in the long term (CH2018, 2018). In general, frequency of heat waves has increased three to four times faster in Europe than in the rest of the northern midlatitudes (Rousi et al., 2022). Third, little adaptation to temperature extremes has taken place, and measures to prevent indoor workplace heat exposure, such as room cooling, are uncommon.[4] Fourth, all employees and registered jobseekers in Switzerland are subject to accident insurance, which allows us to obtain nationwide estimates as well as to examine the totality of occupations and industries in Switzerland. Fifth, due to the design of the social insurance system, the reporting rate for nonfatal workplace accidents in Switzerland is likely to be close to one hundred percent (SSUV, 2021), much higher than in most other countries, where underreporting of occupational accidents is a widespread problem (Hämäläinen et al., 2006).[5] In Switzerland, all parties involved have a great interest in occupational accidents being handled by the statutory work accident insurance, since injured employees no longer have to contribute to the treatment costs and employers, which are obliged to continue paying wages in the event of an accident-related incapacity to work, are compensated by the insurer.

We contribute to two strands of the economics literature. First, this work contributes to the

[4] Of the 529 million air conditioners installed in commercial buildings worldwide, only 53 million units are installed in Europe as a whole, compared to 132 million units in the United States alone (IEA, 2018). In the residential sector, only 5 percent of Swiss households have air conditioning (Randazzo et al., 2020).

[5] For instance, Kurppa (2015) estimates that the reporting rate for nonfatal occupational accidents in some Northern European countries is less than 50 percent. This is because the reporting system in these countries is not insurance-based but based on the employer's legal obligation to report accidents to national authorities. In such systems, benefits for the victim do not depend on prior reporting of the accident (Eurostat, 2013). For the United States, Boden & Ozonoff (2008) and Joe et al. (2014) point to substantial underreporting of nonfatal occupational accidents and illnesses, with less than 70 percent of workplace accidents covered by workers' compensation systems in some states.

growing climate economics literature that points to the adverse consequences of exposure to suboptimal temperature levels across many domains including negative effects on physical performance (Sexton et al., 2022) and cognitive attainment (Graff Zivin et al., 2018; Park et al., 2020). Much of the literature to date has focused on general health outcomes such as mortality and morbidity (Deschênes & Greenstone, 2011; Barreca et al., 2016; White, 2017). If the effects of extreme temperature exposure in the workplace are analysed, the studies typically focus on its impact on workers' labor supply, allocation, productivity, and absenteeism (Graff Zivin & Neidell, 2014; Somanathan et al., 2021; Jessoe et al., 2018; Colmer, 2021; LoPalo, 2023). We contribute to the literature by combining the analysis of the effects of temperature on occupational health and labor supply to provide a more comprehensive picture. Second, we provide new insights into the determinants of workplace safety in general. Prior research includes investigations of the causal impact of other environmental stressors (Lavy et al., 2022; Curci et al., 2023), publicizing safety and health regulation violations (Johnson, 2020), workplace inspections (Johnson et al., 2022), changes in product demand (Charles et al., 2022), international trade (McManus & Schaur, 2016), firm financing (Cohn & Wardlaw, 2016), macroeconomic downturns (Boone & Van Ours, 2006; Boone et al., 2011), as well as immigration (Dillender & McInerney, 2020). This work provides evidence that avoiding exposure to suboptimal temperatures in the workplace is an important factor in occupational health. The research that comes closest to this study is the seminal work of Dillender (2021) and Park et al. (2021) as well as the contemporaneous studies by Ireland et al. (2023) and Filomena & Picchio (2023). Apart from the different institutional settings that, for example, ensure near-total reporting of workplace accidents and the different climatic conditions, we differ from previous studies in that we provide an in-depth discussion of possible health-related mechanisms underlying this relationship and workers' avoidance behavior in the form of labor supply adaption.

This paper proceeds as follows. Section 2 presents the institutional background. Section 3 introduces the data, and provides some summary statistics. Section 4 lays out the empirical strategy. Section 5 presents the results. Section 6 discusses potential health-related mechanisms underlying the relationship between temperature and workplace accidents. Section 7 shows labor supply adjustment to extreme temperatures. Section 8 calculates the number and costs of additional temperature-related workplace accidents. Finally, section 9 concludes.

2 Institutional Setting

In Switzerland all employees have been compulsorily insured against occupational accidents and diseases in accordance with the Accident Insurance Act (UVG) since 1984. In addition, individuals who work at least eight hours per week are insured against leisure-time accidents. The Accident Insurance for the Unemployed (UVAL) was introduced in 1996 and provides compulsory accident insurance coverage for all registered job-seekers in Switzerland. In 2019, 4.81 million people in Switzerland were subject to the accident insurance obligation, which is more than half of the country's population (SSUV, 2020). Since the focus of the paper is on workplace accidents, we only consider workplace accidents of employed persons. In total, there are about 30 individual private or public accident insurance companies in Switzerland. Companies operating in certain industries, such as construction or transportation, are required to take out accident insurance with the *Schweizerische Unfallversicherungsanstalt* (Suva), which is the largest accident insurer in Switzerland. The incentive structure in the Swiss accident insurance ensures almost complete reporting. All parties involved have a great interest in occupational accidents being handled by the statutory accident insurance, since the injured employees no longer have to contribute to the costs of treatment and the employers, who are obliged to continue paying wages in the event of incapacity to work due to an accident, are compensated by the insurer.

By international standards, workplaces in Switzerland are considered safe, with an incidence of 1.4 fatal occupational accidents per 100,000 workers in 2019, compared with an average of 1.7 and 3.5 fatal accidents in the EU and US, respectively (Eurostat, 2019; BLS, 2020).[6] The number of inspectors per 10,000 employees is a further indicator of occupational safety and health[7], and is 1.2 in Switzerland in 2019, compared with 0.1[8] in the United States (ILO, 2022). In Switzerland, there are two main laws that govern occupational health and safety. The Labor Act (ArG) regulates general health protection of workers, working hours, and rest periods. The Accident Insurance Act (UVG) regulates the prevention of occupational accidents and diseases. The Swiss Federal Coordination Commission for Occupational Safety (FCOS) is responsible for monitoring and coordinating the implementation of the regulations (EU-OSHA, 2022).

[6] Compared with the incidence of nonfatal accidents, the incidence of fatal occupational accidents is a more meaningful measure for cross-national comparisons of workplace safety because of the assumed higher reporting rate for fatal accidents.

[7] According to the ILO, the number of inspectors in proportion to the number of employed persons should be 1/10,000 in industrialized countries.

[8] The number refers to the year 2015 which is the latest year for which data is available.

Regarding extreme temperature exposure in the workplace, there are no specific temperature thresholds that allow workers to claim heat-free or cold-free periods.[9] However, the room temperature, air velocity, and relative humidity must be monitored and adjusted to provide an indoor environment that is healthy and appropriate for the type of work being performed. If the work has to be carried out outdoors, employees have to be protected from the adverse effects of exposure to excessive sunlight, heat, cold and weather. The Swiss State Secretariat for Economic Affairs (SECO) proposes specific measures to implement these regulations. For example, employers are advised to protect the health of employees on hot days or ice days through technical (e.g., shading facades and windows, erecting sun tents, installing fans or radiant heaters) and organizational (e.g., adjusting working hours and using flextime arrangements, distribution of warm drinks, providing warm-up times) measures (SECO, 2022). There are awareness campaigns aimed at employers and employees to inform them about precautions and help them implement them. The concrete realization of the measures is in the hands of the employers.

3 Data and Summary Statistics

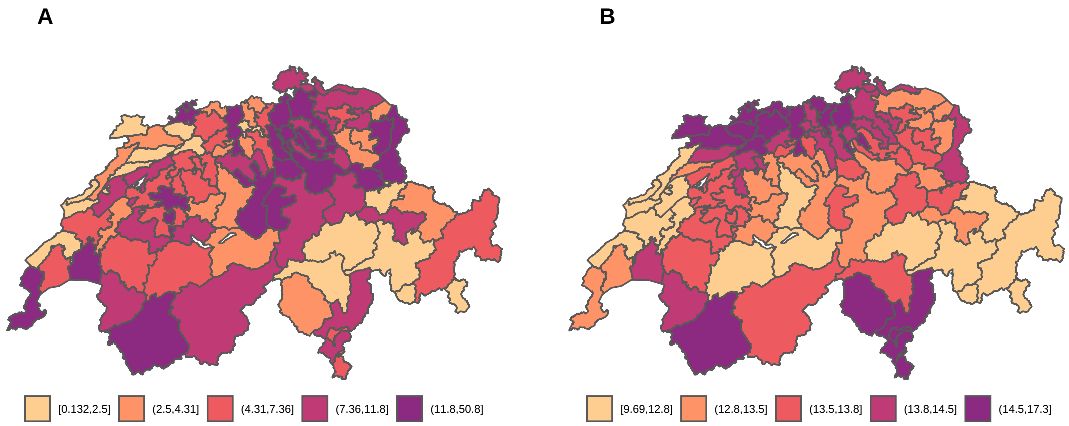
To estimate the impact of temperature on workplace accidents, we rely primarily on two data sources. The first data source is administrative data on the universe of reported workplace accidents in Switzerland. The other consists of historical station-level measurements from Swiss weather monitors, which we use to aggregate the daily weather conditions. To investigate potential mechanisms and labor supply adaptions, we additionally draw on two sets of representative Swiss survey data. To infer the impact of climate change on workplace accidents, we resort to station-level climate prediction data.

Accident Insurance Claims - All accident insurance claims are collected by the *Sammelstelle für die Statistik der Unfallversicherung* (SSUV), which compiles the joint statistics of all insurers. The SSUV is based at the *Schweizerische Unfallversicherungsanstalt* (Suva). We obtain individual-level data on all reported workplace accidents in Switzerland from 1996 to 2019 from the SSUV. Approximately two-thirds of accidents reported to the accident insurance institutions are leisure-time accidents, with the remainder being workplace accidents and a small fraction of accidents reported by registered job-seekers.[10] Accidents on the way

[9] An exception are pregnant workers. There is a set upper and lower temperature limit of 28°C and -5°C in the workplace.

[10] A total of 868,159 accidents were reported in 2019. Workplace accidents accounted for 278,736 (32.1%), leisure-time accidents accounted for 573,955 (66.1%), and accidents reported by job-seekers accounted for 15,468 (1.8%) (SSUV, 2020).

Figure 1: (A) average daily workplace accidents and (B) average maximum daily temperature in Switzerland, 1996 - 2019



Notes: The left panel (A) shows the average number of daily workplace accidents by two-digit zip code in Switzerland during the observation period (1996-2019). The right panel (B) shows the average maximum daily temperature by two-digit zip code in Switzerland during the observation period (1996-2019).

from and to work are considered non-occupational accidents.[11] Since the focus of this paper is on the safety effects of temperature exposure in the workplace, we focus on workplace accidents only. As all employees are subject to accident insurance and the incentive structure ensures almost complete reporting, the data used in this study essentially represent the universe of occupational accidents in Switzerland.

The dataset includes a total of 6,055,594 workplace accident reports, of which we know the exact date of the accident and the two-digit zip code of the injured party's employer.[12] As there is a total of 83 two-digit zip codes[13] in Switzerland, the data is at a low level of spatial aggregation. In addition, each individual data entry contains information about demographic and socio-economic characteristics of the injured party, including age, gender, nationality, industry code of the employer (NACE), major occupation (ISCO), and insured income[14], as well as information on the cause and consequences of the accident including medical expenses

[11]For individuals who work less than eight hours per week, commuting accidents are considered occupational accidents as they are not insured against leisure-time accidents.

[12]It is possible that the zip code of the the injured party's employer does not match the zip code where the accident occurred. For example, some companies that operate nationwide report accidents using the location of their headquarters. In Appendix A of the paper we discuss this in more detail and show that this does not affect our results.

[13]The average population of a two-digit zip code was around 103,661 in 2019. The average size of a two-digit zip code is 497 km^2.

[14]As the insurer does not pay a daily allowance for accident victims who return to work no later than the third day after the accident, this information is only available for accidents with at least three work days lost (41% of sampled accidents). Insured earnings are right-censored. There is a maximum amount of insured earnings that is set to be between the 92nd and 96th percentile of the earnings distribution in a given year. In 2019, the maximum amount was at CHF 148,200.

and the number of compensated work days lost.[15] Individual insurance claims are aggregated at the day and two-digit zip code level resulting in 727,578 zip-code-day cells.

Panel A of Figure 1 shows the geographical distribution of the raw count of workplace accidents in Switzerland. The number of occupational accidents shows large spatial variation, and most incidences are reported in urban zip codes. On average, there are 8.3 occupational accidents per zip-code per day over the course of the observation period. We show the evolution of the average daily number of workplace accidents per year from 1996 to 2019 in Figure B.1 in the Appendix. The evolution of the average daily number of workplace accidents by week of the year and by day of the week are presented in Figure B.2 and B.3 in the Appendix, respectively.

Survey Data - To investigate health-related mechanisms, we additionally draw on six waves (i.e., 1992, 1997, 2002, 2007, 2012, 2017) of the Swiss Health Survey (SHS) administered by the Swiss Federal Statistical Office (BFS). The SHS is a nationally representative cross-sectional survey in which more than 20,000 adults are questioned every five years since 1992 about their health status and health-related behavior in order to periodically monitor the health status of the Swiss population. The survey consists of two parts. First, a telephone interview takes place in which interviewees are asked about their health and health-related behavior, including their alcohol consumption in the last seven days prior to the telephone interview and insomnia and loss of energy in the 30 days prior to the telephone interview. Subsequently, the subjects receive a written questionnaire with additional questions, including questions on insomnia, concentration difficulties, and energy loss in the past 14 days prior to the written survey.[16] Since the SHS reports the respondent's canton[17] of residence as geographic identifier we aggregate station-level weather data to the canton level. By linking weather conditions and the SHS based on the date of the survey and the canton of the respondent, the anonymized microdata set allows us to examine possible health-related

[15]See Table C.1 in the Appendix for a summary of the variables.

[16]The health questions of the written questionnaire used for our analysis were introduced in 2002. In general, more than 85% of the respondents of the telephone interview answer the written questionnaire. We obtain the date of the first part of the survey, the telephone interview, for all survey waves. For the second part of the survey, the written questionnaire, we receive the date on which the written questionnaire was received by the BFS. To arrive at the date of completing the written survey we subtract two days to account for delivery time. We only obtain the date on which the written questionnaire was received by the BFS for the survey waves from 2007 to 2017. For the wave in 2002, we impute the date of the written survey using the median number of days between the telephone interview and the date of the written survey from 2007 to 2017. Since 2012 the written survey can be also be answered online. For the online written survey we know the exact date the questionnaire was filled out.

[17]There are 26 cantons in Switzerland. The average population of a canton was around 330,919 in 2019. The average size of a canton is 1,588 km^2.

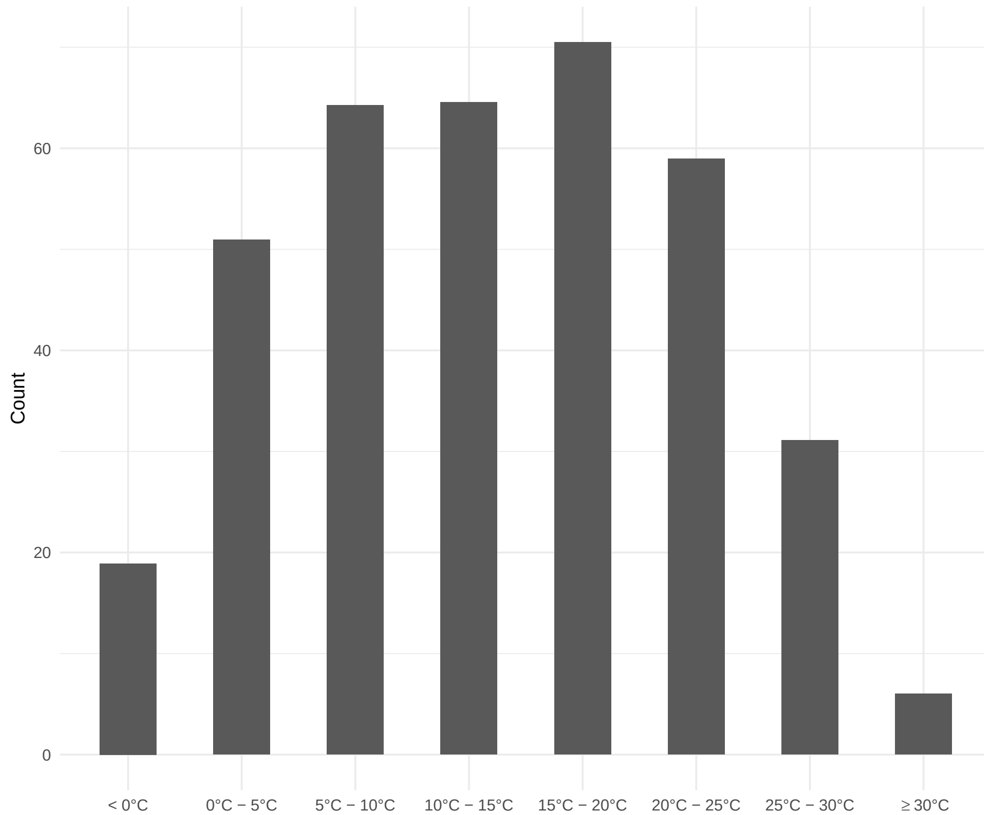
associations between temperature and occupational health. Since we are interested in occupational health, we restrict our sample to working-age individuals between the ages of 15 and 65. In total, our SHS sample consists of around 90,000 observations. We show summary statistics in Table C.2 in the Appendix.

To examine labor supply adaption, we use individual-level data from the Swiss Labor Force Survey (SLFS) from 2010 to 2019 also administered by the Swiss Federal Statistical Office. The SLFS is a nationally representative rotating panel survey with around 120,000 interviews per year to provide information on the structure of the labor force and employment behavior in Switzerland. The questions relate to the respondent's labor market situation, including a question on actual hours worked in the week prior to the interview. The SLFS has been conducted since 1991. Since 2010, the survey is conducted quarterly, which allows us to investigate possible adaptation behavior to extreme temperatures in the workplace. To assign weather conditions, we use the respondent's district of residence and aggregate station-level weather data to the district level.[18] We again restrict our sample to individuals in the labor force who are between the ages of 15 and 65. In total, our SLFS sample consists of around 420,000 observations. We show summary statistics in Table C.2 in the Appendix.

Historical Weather Data - Station-level weather data are obtained from IDAWEB, a research and teaching database by MeteoSwiss, the Swiss Federal Office of Meteorology and Climatology. We extract daily information on temperature (minimum, mean, and maximum temperature), sum of precipitation, mean solar radiation, and mean near-surface wind speed from 1996 to 2019. To combine station-level weather realizations and zip code level workplace insurance claims we aggregate the weather measurements to the two-digit zip code level by taking an inverse-distance weighted average of all observations from stations located within a predefined range to each zip code's geographical center. Panel B of Figure 1 documents average maximum temperatures by two-digit zip code across Switzerland. Visual inspection indicates that there is considerable geographic heterogeneity in temperatures across the country. For the empirical strategy, we bin daily maximum temperature observations in equal-sized intervals of five degrees. The choice of cut-off points in the lower and upper part of the temperature distribution is informed by common climatological threshold days. An ice day is an observational day where the maximum air temperature is below freezing (i.e,

[18]There are 148 districts in Switzerland. The average population of a district was 58,134 in 2019. The average size of a district is 279 km^2. Geographic identifiers are available at the municipality level in our data set which we then aggregate to the district level. Information on the location are available for two-thirds of the interviews because location of respondents is only released for individuals from municipalities with populations greater than 5,000.

Figure 2: Average number of days per year in the respective temperature ranges, 1996 - 2019



Notes: This figure shows the historical average distribution of daily maximum temperatures in Switzerland across eight temperature bins during the observation period (1996-2019). Each bar depicts the average number of days in each temperature interval in a year.

$T_{max} < 0°C$), summer days and hot days are days with a maximum air temperature of above 25°C (i.e, $T_{max} > 25°C$) and at least 30°C (i.e, $T_{max} \geq 30°C$), respectively.[19] In Figure 2, the height of each bar represents the average number of days per year in each temperature category for an average Swiss zip code area. The mean number of days is 18.9 for ice days and 6.0 for hot days. We show the evolution of the average number of extremely hot and cold days per year in Switzerland from 1996 to 2019 in Figure B.4 in the Appendix. The graphs indicate a pronounced upward trend in the number of hot days and a slight decrease in the number of ice days.

To combine the station-level weather data with the survey data, we use the same procedure as for the accident insurance claims, but aggregate weather data to the canton (for the SHS data) and district level (for the SLFS data), respectively.

[19] Additionally, we divide the daily precipitation total (mm) into five groups that correspond to MeteoSwiss' definition of precipitation intensity (i.e, 0; 0.1-2; 2-10; 10-30; >30).

Climate Change Scenarios - To approximate the number and costs of temperature-driven workplace accidents at the end of the century, we use station-level weather predictions from the CH2018 Climate Change Scenarios (CH2018, 2018) by the Swiss National Centre for Climate Services (NCSS). The CH2018 Climate Change Scenarios provide daily projections for meteorological stations in Switzerland estimated on the basis of three different Representative Concentration Pathways (i.e., RCP8.5 - unabated emissions; RCP4.5 - 2°C-non-compliant mitigation; RCP2.6 - 2°C-compliant mitigation) for a range of different climate models. To predict the impact of climate change on temperature-related occupational accidents, we draw on projections for the period 2070-2099 from the KNMI regional atmospheric climate model (RACMO22E) driven by the Hadley Centre Global Environment Model version 2 (HadGEM2).[20] To aggregate the station-level observations to the zip code level, we follow the same procedure as for the historical weather data. Table C.3 shows the expected number of days per year in each temperature bin at the end of the century for an average Swiss zip code area. Hot days are projected to increase to 8.4 and 35.2 days per year, and ice days are projected to decrease to 14.2 and 3.6 days per year under the RCP2.6 and RCP8.5 scenarios, respectively.

4 Empirical Strategy

For our baseline estimation of the effect of temperature on workplace accidents, we choose a count data model, which is based on several aspects of our data. Our accident outcome follows an implicit count process and only takes non-negative integer values. Additionally, there are zero count observations, which occur due to the high spatial and temporal granularity of our workplace accident insurance claim data.[21] Therefore, we estimate in the most extensive specification the following Poisson fixed effects model using Pseudo-maximum likelihood:

$$\text{Workplace Accidents}_{it} = \exp\Big(\sum_{j\in J\setminus\{10-15\}} \beta^j \mathrm{T}^j_{it} + W'_{it}\gamma + \mu_{iw} + \delta_{cmy} + \delta_t + \epsilon_{it}\Big), \qquad (1)$$

where the dependent variable represents the number of workplace accidents reported in two-digit zip code i at day t. T^j_{it} are indicators for the temperature bin that includes T_{max}

[20] We choose this climate simulation for two reasons. First, the climate simulation is available for three different emission scenarios. Second, the climatic parameter of interest for our study is close to the median value across all simulations of the unmitigated emissions scenario (RCP8.5) produced by various climate models (CH2018, 2018).

[21] 14.2% of zip-code-day cells contain no workplace accidents.

for j $\in$ J = {<0, 0-5,..., 25-30, $\geq$30}, as shown in Figure 2. We omit the temperature bin that indicates whether the maximum daily temperature on a given day is larger than 10°C but equal to or less than 15°C. W_{it} is a vector of covariates that controls for on-the-day precipitation intensity, wind strength, and solar radiation. The model includes a full set of zip-code-by-week fixed effects, μ_{iw}, to control for permanent unobserved zip-code-by-week determinants of occupational accidents, such as fixed differences in workplace safety or seasonal employment. The inclusion of week fixed effects rather than month fixed effects allows us to measure seasonality at a more granular level.[22] δ_{cmy} are region-by-year-month fixed effects to control for idiosyncratic changes in workplace accident outcomes (e.g., macroeconomic shocks), which are allowed to vary at the region (one-digit zip code) level, to adjust for region-specific trends over time. To increase precision of estimates, we account for trends in the occurrence of occupational accidents within the week and on national holidays by including day-of-week and holiday indicators, δ_t. We cluster standard errors at the region-year level. Assuming that the temperature variation, conditional on the covariates and the rich set of fixed effects, is orthogonal to unobservable determinants of the number of workplace accidents, the β^j can be interpreted as the causal effect of temperature on occupational safety.

5 Results

5.1 Baseline Results

The results from estimating our main model of interest are depicted in Table 1. We begin by estimating a reduced version of the specification outlined in equation (1), controlling only for zip code, year, and week fixed effects in column (1). In column (2), we include day-of-week and holiday fixed effects to account for general trends in workplace accidents that are driven by nationwide holidays and specific days of a week. In column (3), we allow for zip code-specific seasonality by including zip-code-by-week fixed effects. In column (4) we additionally interact the year fixed effects with an indicator for one-digit zip code. Next, in column (5), we account for macroeconomic trends on a time-wise more granular level by including year-month fixed effects. In column (6), in our preferred specification, we control for zip code-specific seasonality in workplace accidents, allow macroeconomic trends to vary at the one-digit zip code level, and control for trends within the week and on holidays. We find that relative to a day with maximum temperatures in the base category (10°C

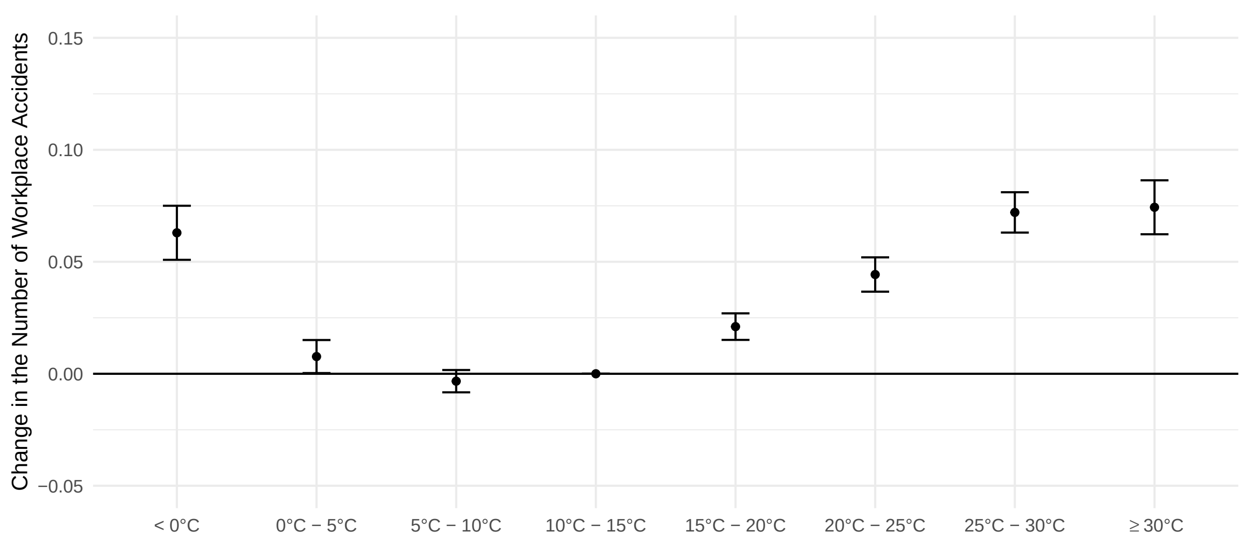
[22] When looking at weekly averages, the annual seasonal pattern becomes especially apparent. We show the average daily number of workplace accidents per week of the year from 1996 to 2019 in Figure B.2 in the Appendix.

Table 1: Temperatures and workplace accidents - main results

	(1)	(2)	(3)	(4)	(5)	(6)
< 0°C	0.074***	0.066***	0.064***	0.064***	0.063***	0.063***
	(0.009)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
0°C - 5°C	0.023***	0.006*	0.008**	0.008**	0.007**	0.008**
	(0.008)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
5°C - 10°C	−0.006	−0.005**	−0.003	−0.003	−0.004	−0.003
	(0.006)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
15°C - 20°C	0.021***	0.023***	0.022***	0.022***	0.021***	0.021***
	(0.007)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
20°C - 25°C	0.065***	0.048***	0.047***	0.048***	0.044***	0.044***
	(0.010)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
25°C - 30°C	0.083***	0.078***	0.080***	0.080***	0.072***	0.072***
	(0.011)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
≥ 30°C	0.115***	0.085***	0.087***	0.085***	0.075***	0.074***
	(0.015)	(0.007)	(0.005)	(0.005)	(0.006)	(0.006)
Num.Obs.	727 578	727 578	727 578	727 578	727 578	727 578
Pseudo R2	0.516	0.681	0.683	0.684	0.684	0.685
Year FE	X	X	X			
Week FE	X	X				
Year x Month FE					X	
Zipcode2 FE	X	X				
Zipcode2 x Week FE			X	X	X	X
Zipcode1 x Year FE				X		
Zipcode1 x Year x Month FE						X
Day of Week FE		X	X	X	X	X
Holiday FE		X	X	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses are clustered at the region-year level. *p<0.1; **p<0.05; ***p<0.01.

Figure 3: Estimated relationship between daily count of workplace accidents and daily maximum temperature



Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures (Table 1 column (5)). The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

- 15°C), the number of workplace accidents is 6.3 percent higher on days with maximum temperatures below 0°C. Relative to days with a maximum temperature in the excluded category, the number of workplace accidents is up to 7.2 percent higher on days with maximum temperatures between 25°C and 30°C (i.e., summer days). The magnitude of the estimate is slightly larger for days with a maximum temperature of at least 30°C (i.e., hot days) and highly significant, despite of the relative rarity of such extreme temperature days in our data. To ease interpretation, Figure 3 depicts the effects of our preferred specification graphically by plotting the coefficients and the corresponding 95% confidence intervals. It shows a pronounced U-shaped relationship between temperature and workplace accidents with increasing intensity toward the end of the temperature spectrum.

5.2 Validity Checks and Robustness Checks

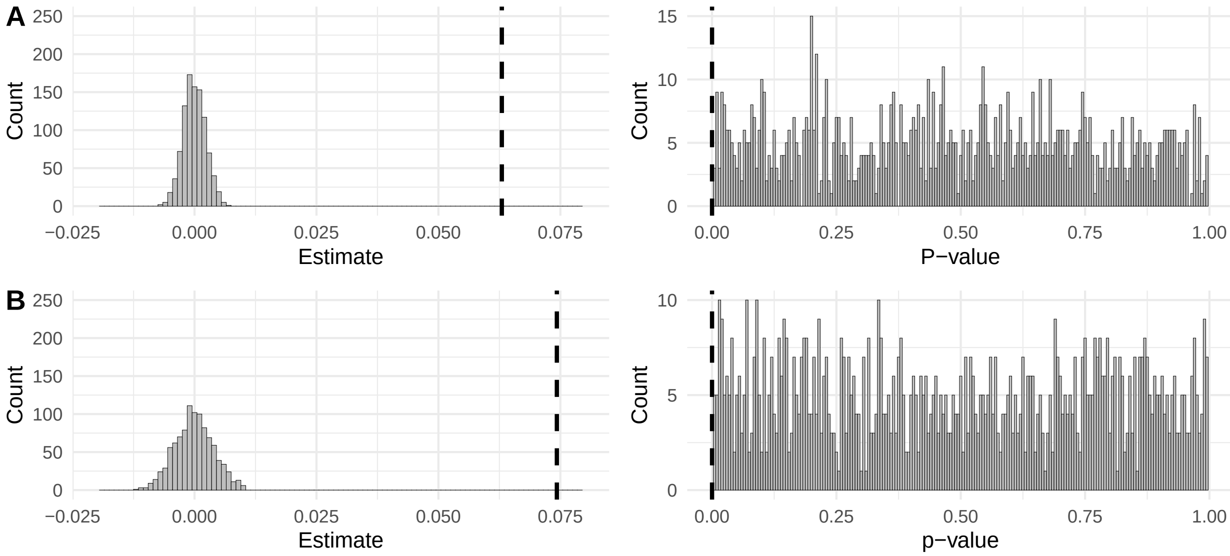
Although we control for weather conditions and a rich set of fixed effects, there might be still unobserved factors that correlate with both temperature and workplace accidents. As a test of whether it is temperatures that are causing the workplace accidents, we randomly shuffle ice days and hot days 1,000 times across date and zip code and estimate our preferred specification for each of the permuted datasets. Panel A of Figure 4 shows the results of the permutation test for ice days, Panel B shows the results for hot days. The dashed vertical lines present the estimates and p-value of our main specification using the real data. For the simulated data, the mean value of the estimate is by construction zero, and the mean p-value is 0.49 for cold and hot days. In all cases our obtained baseline estimate is more extreme than all of the 1,000 placebo estimates. This suggests that our results are due to on-the-day temperatures and not due to random chance.

In another robustness check, we additionally estimate the regression of workplace accidents on temperature by OLS and use either the raw count of the number of workplace accidents as the dependent variable or the inverse-hyperbolic sine transformation.[23] Results are presented in Table C.4 in the Appendix. The results resemble the findings of our baseline model with increasing magnitude of coefficients toward the end of the temperature spectrum. All models confirm the existence of a significant impact of ice days, summer days, and hot days on the number of workplace accidents.

Also, we test the robustness of our results to different level of clustering. In our main specification we cluster standard errors at the region-year level. In Table C.5 in the Appendix we present results using different levels of clustering, including, for example, standard errors that adjust for spatial correlation based on a fixed radius (Conley, 1999). The significance

[23] The inverse hyperbolic sine (arsinh) behaves similarly to the natural logarithm, but allows for retaining zero-valued observations.

Figure 4: Permutation test



Notes: This figure illustrates the simulation-based null distribution of the regression estimates and p-values for A: <0°C and B: ≥ 30°C. The horizontal line represents the results of our estimation, A: 0.063 (p = 0.00) and B: 0.074 (p = 0.00). Extreme temperature days are randomly permuted 1,000 times across zip-code-day observations and the baseline model outlined in equation (1) is re-estimated for each of these 1,000 simulated datasets.

of the coefficients is virtually unchanged.

Next, we test for sensitivity of the results to a change in the measure of temperature and the temperature cut-off points. We estimate the main specification using temperature bins that include mean daily temperatures instead of maximum daily temperatures. Also, we estimate the model dividing the temperature into 2.5-degree bins and 3.75-degree bins instead of five-degree bins, respectively.[24] Results are presented in Figure B.5 and Figure B.6 in the Appendix. Again, the results show an U-shaped relationship between temperature and workplace accidents.

Lastly, we test whether the results are robust to weighting the regression by the total number of full-time equivalents of the two-digit zip code in each year.[25] Results are shown in Figure B.7 in the Appendix. The results of the weighted regression are similar to the unweighted regression.

[24]We choose this subdivision to obtain bins of equal size while having constant thresholds based on the climatological threshold days at the lower and upper ends of the temperature distribution.

[25]Because data on full-time equivalents per two-digit zip code are only available from 2011, the observation period in the following analysis ranges from 2011-2019.

5.3 Subgroup Analysis

Demographics and socio-economic characteristics - We investigate whether the effects differ by demographic and socio-economic characteristics of workers as climate change might potentially contribute to within-country inequalities. We expect that outdoor temperature will affect workers with relatively dangerous and heavy physical jobs, i.e., male, low-income, and migrant workers relatively more.[26] Consistent with previous literature on health impacts of temperature exposure (e.g., Deschênes & Greenstone, 2011), we expect that the effects on occupational health also differ by worker age. Also in related work Park et al. (2021) show that hot days specifically impact the workplace accidents of young and low-income workers, and that effects are larger for men than for women. Contrary to our hypothesis, we find that our effects are robust to various subgroups, and that no specific subgroup drives the effects (see Table 2). For all subgroups, we find that the magnitude of the effects is increasing towards the end of the temperature spectrum. There is no evidence of a meaningful difference in the effect size between men and women or between different nationalities. While there is no statistically significant gap between the increase in the number of heat-related occupational accidents between older and younger workers, the effect of an additional ice day is significantly larger for older workers. For all income groups, the impact of a hot day increases the number of workplace accidents equally relative to a day in the omitted category. However, our findings show that the number of occupational accidents of the highest income group increase significantly more due to an additional ice day. A potential explanation for this result is that there is a particularly high share of injured employees above the age of 50 among the highest income quantile.[27] Overall, the results are in contrast with Park et al. (2021), who find that rising temperatures contribute to increasing labor market inequality in the United States in terms of workplace safety risks.

[26] In Switzerland, the injury risk per 1000 workers is the highest for the primary and secondary sector (SSUV, 2021). In 2019, 32.4% of men and only 12.6% of women worked in the primary or secondary sector. 21.7% of Swiss workers and 26.8% of migrant workers were employed in the primary or secondary sector.

[27] In our sample, 34% of the injured in the highest income quantile are 50 years or older, whereas only 7% are younger than 30 years.

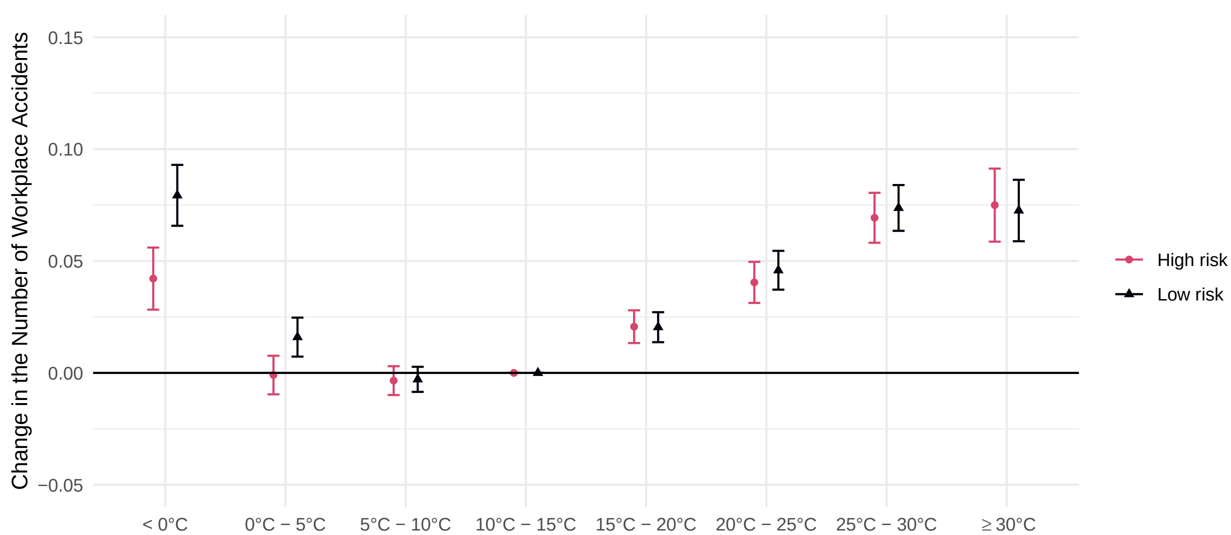
Table 2: Estimated relationship between daily count of workplace accidents and daily maximum temperature by demographic and socio-economic characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Gender		Age			Nationality			Income Quantile				
	M	W	<30	30-50	>50	Swiss	Neighbour	Other	Q1	Q2	Q3	Q4	Q5
< 0°C	0.057***	0.084***	0.014**	0.067***	0.141***	0.067***	0.062***	0.050***	0.083***	0.060***	0.067***	0.129***	0.165***
	(0.006)	(0.008)	(0.006)	(0.007)	(0.010)	(0.007)	(0.010)	(0.009)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)
0°C - 5°C	0.005	0.019***	−0.008*	0.011**	0.028***	0.008*	0.005	0.009	0.011	0.009	0.008	0.037***	0.052***
	(0.004)	(0.006)	(0.005)	(0.005)	(0.006)	(0.004)	(0.007)	(0.006)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)
5°C - 10°C	−0.003	−0.003	−0.003	−0.003	−0.004	−0.002	−0.003	−0.007	0.002	−0.007	−0.008	0.011*	0.012**
	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)	(0.005)	(0.004)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
15°C - 20°C	0.023***	0.014***	0.019***	0.021***	0.026***	0.022***	0.021***	0.018***	0.017***	0.020***	0.022***	0.021***	0.031***
	(0.003)	(0.005)	(0.004)	(0.003)	(0.004)	(0.003)	(0.005)	(0.004)	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)
20°C - 25°C	0.044***	0.044***	0.045***	0.043***	0.047***	0.045***	0.046***	0.040***	0.044***	0.054***	0.038***	0.043***	0.054***
	(0.004)	(0.006)	(0.005)	(0.005)	(0.006)	(0.004)	(0.007)	(0.005)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
25°C - 30°C	0.072***	0.071***	0.076***	0.071***	0.067***	0.069***	0.079***	0.075***	0.055***	0.086***	0.074***	0.075***	0.093***
	(0.005)	(0.007)	(0.006)	(0.006)	(0.007)	(0.005)	(0.008)	(0.007)	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)
≥ 30°C	0.073***	0.075***	0.079***	0.070***	0.076***	0.070***	0.079***	0.084***	0.068***	0.082***	0.077***	0.103***	0.097***
	(0.007)	(0.010)	(0.009)	(0.008)	(0.010)	(0.007)	(0.012)	(0.010)	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)
Num.Obs.	727 578	727 578	727 578	727 578	727 578	727 550	727 186	721 220	727 578	727 578	727 578	727 578	727 578
Pseudo R2	0.642	0.489	0.500	0.568	0.437	0.611	0.473	0.477	0.311	0.326	0.337	0.347	0.398
Zipcode2 x Week FE	X	X	X	X	X	X	X	X	X	X	X	X	X
Zipcode1 x Year x Month	X	X	X	X	X	X	X	X	X	X	X	X	X
Holiday FE	X	X	X	X	X	X	X	X	X	X	X	X	X
Day of the Week FE	X	X	X	X	X	X	X	X	X	X	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses are clustered at the region-year level. *p<0.1; **p<0.05; ***p<0.01.

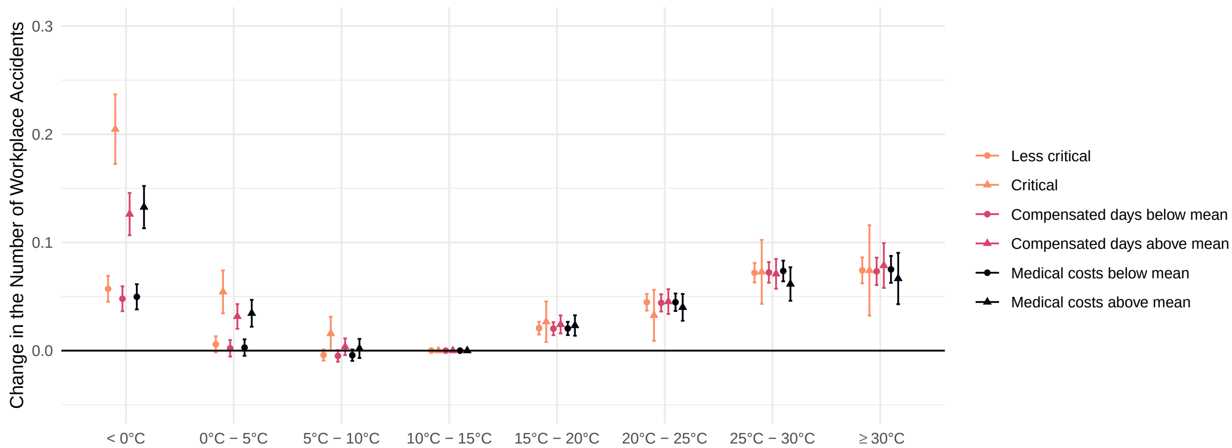
Industry - To explore differential impact of temperatures by economic sectors we follow the literature (e.g., Graff Zivin & Neidell, 2014; Rode et al., 2022) and classify agriculture, mining, manufacturing, utilities, and construction as high-weather-exposed industries (high-risk) and all remaining sectors as low-weather-exposed industries (low-risk). We expect temperature extremes to have larger impacts on the number of workplace accidents in industries where weather exposure of workers is greater. Figure 5 depicts a U-shaped relationships between temperature exposure and the number of occupational accidents for both high-risk and low-risk industries. We do not find evidence that the effects of hot days differ significantly across industries. However, the coefficient for ice days is significantly larger for low-risk industries providing suggestive evidence of a stronger impact of cold temperatures on low-risk industries. The results for each individual industry are shown in Table C.6 in the Appendix. The dose response function between the count of daily workplace accidents and daily maximum temperature follows the U-shaped pattern of increasing intensity toward the end of the temperature distribution for most industries, even though hot day effects are imprecisely estimated for some industries. Results suggest strongest effects of ice days for mining, communication, and real estate, and strongest effects of hot days for agriculture, construction as well as professional, scientific, technical, administrative, and support services.

Figure 5: Estimated relationship between daily count of workplace accidents and daily maximum temperature by risk of outdoor exposure



Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by industry. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure 6: Estimated relationship between daily count of workplace accidents and daily maximum temperature by (economic) severity



Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by severity of the accident. Coefficients are obtained by applying the full model in equation (1) to the respective subsample. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

(Economic) severity - Next, we look at the effects of exposure to suboptimal temperature on occupational accidents by severity of the accidents. We use three different measures for severity: critical vs. less critical, compensated days, and medical costs. Accidents are classified as critical if the person is unable to work for more than 90 compensated days, receives a disability pension or dies as a result of the accident. The remaining accidents are defined as less critical. The compensated days are a more accurate measure of the severity of an accident. It calculates the amount of compensation divided by the daily allowance rate. We consider compensated days above the mean to be more severe accidents, while compensated days below the mean are considered less severe accidents. Medical costs are also an indicator of the severity of an accident. We define medical costs above the mean to be more severe accidents, while medical costs below the mean are less severe accidents. Figure 6 presents the results. For all three measures, we find a significant impact of temperature on workplace accidents, both for accidents defined as severe and non-severe. There is no statistically significant discrepancy in the effect size between the number of heat-related occupational accidents by severity. However, an additional ice day increases the number of accidents categorized as severe more.

Adaptation - To test indirectly for potential adaptation, we explore heterogeneity in the temperature effects on workplace accidents along several dimensions (Dell et al., 2014; Hsiang, 2016). We stratify the sample by the long-run temperature of regions (e.g., Deschênes & Greenstone, 2011), time period (e.g., Park et al., 2021), and urban status (e.g., Burgess et al., 2017). First, we examine whether workers adapt to suboptimal temperature levels depending on whether they work in relatively warmer or relatively colder regions.[28] According to the adaption hypothesis, an additional hot day would increase occupational accidents more strongly in colder regions than in warmer regions, while an additional ice day would affect occupational accidents more in relatively warm regions. Our results, presented in Figure B.8 in the Appendix, suggest that there is no statistically significant difference in the effect size between relative warm and cold regions, even though the point estimate is larger in magnitude for ice days in warmer regions. Second, we examine whether there has been adaptation to temperature extremes over time. To do so, we divide the sample into the periods 1996-2005 and 2006-2019 and re-estimate our baseline regression equation for each of the split samples. We find no statistical difference in the effects over time, though the point estimate is larger for hot days during 1996-2005 (Figure B.9 in the Appendix). Third, we investigate whether the effects differ by urban status.[29] The results are depicted in Figure B.10 in the Appendix and show no difference in effect sizes based on urban status.

5.4 Lagged Effects

Thus far, this study focuses on immediate temperature impacts and ignores potential build-up effects of temperatures. Occupational accidents may be the result of multi-day exposure to extreme temperatures, for example, due to a temperature-induced decline in sleep quality (Obradovich et al., 2017). Previous literature suggests a dynamic relationship between health outcomes and temperature exposure (e.g., Deschenes & Moretti, 2009; White, 2017). We explore the impact of lagged temperature extremes on workplace accidents by following the approach of Somanathan et al. (2021). More specifically, to analyse the impact of lagged exposure to extreme temperature, we augment our baseline model outlined in equation (1) and estimate the following equation:

$$\text{Workplace accidents}_{it} = \exp\Big(\sum_{j \in J \setminus \{10-15\}} \beta^j \mathrm{T}^j_{it} + \sum_{j \in J \setminus \{10-15\}} \zeta^j \mathrm{L}^j_{it} + W'_{it}\gamma + \mu_{iw} + \delta_{cmy} + \delta_t + \epsilon_{it}\Big), \tag{2}$$

[28]We define ‘relative warm regions‘ as zip codes with an average maximum temperature above the 80th percentile of the temperature distribution in Switzerland over the entire observation period (> 14.5°C). ‘Relative cold regions‘ are zip codes with an average maximum temperature below the 20th percentile (< 12.8°C). The classification is depicted in Panel B of Figure 1.

[29]We use the urban-rural classification by BFS. Two-digit zip codes are classified based on whether the majority of municipalities in that two-digit zip code are classified as urban, intermediate, or rural.

where L^j_{it} is the count of the number of days that fall in the jth temperature bin in the seven days prior to the accident. We again exclude the temperature bin that includes the count of the number of days in the seven days prior to the accident with maximum temperatures larger than 10°C but equal to or less than 15°C. The rest of the equation is similar to the equation above, with T^j_{it} again being the indicator for on-the-day temperatures.

Table 3 suggests that an additional ice day in the previous seven days has no effect on on-the-day workplace accidents, while an additional hot day in the previous seven days increases on-the-day workplace accidents.[30] For all industries, the effect of an additional ice day in the seven preceding days is zero and insignificant, suggesting that past cold temperatures have no effect on the number of occupational accidents today. The contemporaneous effect is similar in magnitude to the estimated effect in the baseline specification without lagged temperatures. We find that an additional summer or hot day in the seven previous days leads to a significant increase in the number of workplace accidents by 1.2%. To see if the effects differ for industries that are potentially more exposed to weather we re-estimate our equation for high-risk and low-risk industries separately. Columns (2) and (3) show that there is no evidence of differential impacts of lagged hot temperatures. Lagged hot temperatures also play a role in low-weather-exposed industries, suggesting temperature exposure outside the workplace. We find that in high-weather-exposed industries an increase in the number of ice days in the past seven days slightly decreases the number of on-the-day workplace accidents, while it increases the number of on-the-day workplace accidents in low-weather-exposed industries. However, the coefficients are small in magnitude suggesting that the influence of preceding ice days on workplace accidents is rather negligible, while the influence of ice days on the day itself is relatively more important for both high and low-weather-exposed industries.

In Figure B.11 in the Appendix we depict the results when we re-estimate our baseline regression including temperature leads and lags. The results confirm the finding that lagged ice days do not impact workplace accidents, while lagged hot days increase workplace accidents. For cold days, we find evidence of the existence of a large on-the-day effect, with no evidence of a temperature-induced temporal substitution of accidents. The coefficient of on-the-day temperatures below the freezing point is close to the one in the baseline specification and the coefficients of lagged and forwarded temperatures are mostly small in magnitude and statistically insignificant for ice days. For hot days, the results indicate a build-up effect.

[30]Our previous results suggest that most of the temperature effects occur on ice, summer, and hot days. Therefore, we only show coefficients for these three temperature bins.

Table 3: Temperatures and workplace accidents - dynamic effects

	(1)	(2)	(3)
	All	High risk	Low risk
< 0°C (T)	0.063***	0.050***	0.074***
	(0.006)	(0.007)	(0.007)
25°C - 30°C (T)	0.056***	0.052***	0.058***
	(0.004)	(0.005)	(0.005)
≥ 30°C (T)	0.052***	0.053***	0.051***
	(0.006)	(0.009)	(0.007)
< 0°C (L)	0.000	−0.005***	0.003**
	(0.001)	(0.002)	(0.002)
25°C - 30°C (L)	0.010***	0.010***	0.010***
	(0.001)	(0.001)	(0.001)
≥30°C (L)	0.012***	0.011***	0.013***
	(0.002)	(0.002)	(0.002)
Num. Obs.	726 997	726 997	726 997
Pseudo R2	0.685	0.525	0.653
Zipcode2 x Week FE	X	X	X
Zipcode1 x Year x Month FE	X	X	X
Day of Week FE	X	X	X
Holiday FE	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses are clustered at the region-year level. (T) refers to contemporaneous effects of temperature exposure and (L) refers to lagged effects. *p<0.1; **p<0.05; ***p<0.01.

The coefficient for on-the-day temperatures is now smaller than in the baseline specification, but the coefficients of lagged temperatures are positive and mostly statistically significant for hot days. The effects of forwarded temperatures are zero and insignificant. Figure B.12 in the Appendix shows that the effects are qualitatively similar for low-risk and high-risk workers.

6 Potential Health-Related Mechanisms

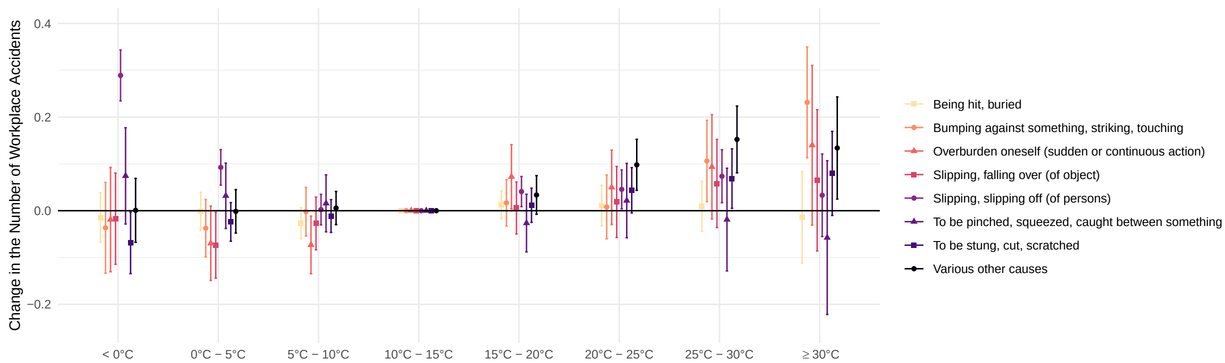
Extreme temperatures can have both direct and indirect effects on occupational health. High temperatures cause a higher breathing and heart rate, and lower blood pressure. This can result in sunstroke, fainting, cramps, exhaustion and fatigue, as well as acute asystolia and respiratory standstill. Cold temperatures can lead to constricted arteries and veins, more viscous blood, a decrease in motor skills, and frostbite (Seltenrich, 2015). Apart from the direct physiological effects, extreme temperatures might indirectly affect workplace accidents. Recent evidence shows that extreme temperature have adverse effects on emotional affect (Baylis, 2020), decision-making (Almås et al., 2019), and physical and cognitive performance (Graff Zivin et al., 2018; Park, 2020; Sexton et al., 2022). By this means, extreme temperatures can lead to an increased number of workplace accidents. To achieve a deeper understanding between the relationship of temperature and workplace safety, we investigate potential mechanisms associated with health and health-related behavior change.

Unfortunately, we do not have data to measure the direct physiological health effects nor the effects on decision-making and cognitive attainment. However, we can provide evidence for the cause of the accident drawing upon the accident insurance claims. Moreover, we analyse how temperatures affect health and health-related behavior changes, such as sleep problems, concentration difficulties, loss of energy, and alcohol consumption using the Swiss Health Survey. We choose these outcomes variables as they are strongly interconnected with decision-making and cognitive attainment (Alhola & Polo-Kantola, 2007).

6.1 Cause of Accident

In a first step, we analyse the effect of extreme temperatures on the cause of the accident. Each year, the SSUV randomly draws five percent of the accidents for which it identifies additional information, including the primary cause of the accident. The most frequent causes of occupational accidents in Switzerland are slipping, slipping off (22%); being hit or buried (21%); being stung, cut or scratched (16%); bumping against something, striking, touching (8%); slipping, falling over (of object) (7%); being pinched, squeezed, caught between something (6%) and overburden oneself (5%). The other 11 causes mentioned in the accident report occur less frequently (see Table C.7 in the Appendix). We group these accidents under the term "various other causes". Notably, there is no category for temperature-induced accidents. We re-estimate our baseline regression separately by cause of the accident. We

Figure 7: Estimated relationship between daily count of workplace accidents and daily maximum temperature by cause of the accident



Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by the six most frequent causes of the accident. "Various other causes" is a combined variable of the remaining other 11 causes of the accidents. Coefficients are obtained by applying the full model in equation (1) to the respective subsample. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

show the effects of temperature on occupational accidents by cause in Figure 7. An additional ice day increases on average the number of accidents caused by slipping by nearly 29% compared to a day in the omitted category. An additional hot day leads to a significant increase in the number of workplace accidents due to bumping against something, striking, touching, and due to being stung, cut or scratched. The number of accidents due to "various other causes" increases as well with higher temperatures, mainly driven by being bitten, hit, stung by animals and insects. An additional hot day also affects the number of accidents due to overburden, but the effect is not significant.

The results provide suggestive evidence that both direct and indirect effects are relevant. On ice days, slipping accidents may increase due to direct physiological reasons (e.g. impaired motor skills) or due to impaired concentration. On hot days, the increase in accidents due to bumping points towards an indirect effect, while the increase in accidents due to self-overloading indicates the role of a direct physiological effect.

6.2 Self-Reported Health and Health-Related Behavior

Next, we resort to the SHS data to examine changes in self-reported health. Temperature-induced changes in health could potentially act as a mechanism underlying the relationship between temperatures and workplace accidents. The SHS asks questions about health symptoms and health-related behavior, such as insomnia, loss of energy, concentration difficulties, and alcohol consumption. To examine possible health-related mechanisms, we estimate the following linear probability model:

$$\text{Health outcome}_{nit} = \sum_{j \in J \setminus \{10-15\}} \beta^j \mathrm{T}_{it}^j + W_{it}'\gamma + X_{nit}'\theta + \mu_{im} + \delta_{my} + \delta_t + \epsilon_{nit}, \qquad (3)$$

where the dependent variable is a binary variable indicating whether individual n residing in canton i at week t reports insomnia, loss of energy or concentration difficulty in the 14 days preceding the written survey, or alcohol consumption in the 7 days preceding the telephone interview.[31] Since the health-related questions refer to the last 7 and 14 days, respectively, T_{it}^j now contains the number of days in the last 7 or 14 days that fall within the

[31]Subjects are asked to indicate how often they suffered from insomnia, loss of energy, or difficulty concentrating in the last 14 days preceding the written survey. We code "not at all" as zero and "on single days", "more than half of the days" or "almost every day" as one. For alcohol consumption, subjects are asked whether they have consumed alcohol in the last 7 days preceding the telephone interview or not. We code "no" as zero and "yes" as one.

Table 4: Temperature and health outcomes - written survey

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Last 14 days			Last 10 days			Last 7 days		
	Insomnia	Loss of Energy	Concentration Difficulty	Insomnia	Loss of Energy	Concentration Difficulty	Insomnia	Loss of Energy	Concentration Difficulty
< 0°C	−0.003	−0.003	0.000	−0.003	−0.005**	0.001	−0.003	−0.008**	0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)
0°C - 5°C	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
5°C - 10°C	0.002	0.000	0.000	0.002	−0.001	0.000	0.002	−0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
15°C - 20°C	0.003**	0.002	0.001	0.004**	0.003*	0.002	0.005**	0.004*	0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
20°C - 25°C	0.002	0.000	0.000	0.003	0.001	0.001	0.002	0.002	0.003*
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
25°C - 30°C	0.005**	0.002	0.003	0.007**	0.005*	0.004*	0.006*	0.004	0.008***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
≥ 30°C	0.007**	0.005	−0.002	0.007*	0.009**	−0.001	0.006	0.009**	0.003
	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
Num.Obs.	52 520	52 475	52 426	52 520	52 475	52 426	52 520	52 475	52 426
R2 Adj.	0.198	0.109	0.468	0.198	0.109	0.468	0.198	0.109	0.469
Canton x Month FE	X	X	X	X	X	X	X	X	X
Year x Month FE	X	X	X	X	X	X	X	X	X
Day of Week FE	X	X	X	X	X	X	X	X	X
Holiday FE	X	X	X	X	X	X	X	X	X

Notes: The sample period is 2002 to 2017. Standard errors in parentheses are clustered at the canton-year level. *p<0.1; **p<0.05; ***p<0.01.

j-th temperature range. We omit the number of days in the last 7 or 14 days with maximum daily temperatures larger than 10°C but equal to or less than 15°C. To control for individual-level determinants of health we include X_{nit}, which includes demographic and socio-economic characteristics of workers. More specifically, we include age, age-squared, gender, marital status, place of birth, and education. W_{it} is a vector of covariates that controls for canton level precipitation intensity, wind strength, and solar radiation in the last 7 or 14 days, respectively. The model includes a full set of canton-by-month fixed effects, μ_{im}, year-month fixed effects, δ_{my}, and indicators for the weekday of the survey, δ_t. The vector of controls also includes the number of holidays in the last 7 or 14 days, respectively. Standard errors are clustered at the canton-year level.

Table 4 shows the results of temperature exposure on self-reported health outcomes. Column (1) shows the results for insomnia. We find evidence that sleep problems increase with increasing temperatures. While an additional ice day in the last seven days does not affect sleep, an additional hot day significantly increases the likelihood of reporting insomnia by 0.7 p.p., which constitutes a 1% increase over the baseline probability of 70%. Column (2) shows the results for loss of energy as an outcome. Our results suggest that the likelihood of reporting a loss of energy is increasing with temperature levels, though the effects are not significant on conventional levels. Column (3) shows the effects of temperature exposure on concentration difficulties. We find no significant effect of temperatures on the likelihood of reporting concentration difficulties.

However, respondents may exhibit a recall bias when reporting health outcomes within the past 14 days. This bias may cause respondents not to consider the entire time period queried when answering questions, but to mentally shorten the time period and focus on a time period closer to the survey date (Tourangeau et al., 2000; Choi & Pak, 2005). Since we do not know exactly what time frame respondents are considering, and it is likely to vary by respondents, we follow the approach of Mullins & White (2019) and provide a number of different estimates. In addition to the last 14 days, we examine the impact on health outcomes using temperatures in the last 10 and 7 days before the written survey.[32] The results in columns (4) to (10) support our main findings. While the temperature effects on insomnia do not change, the coefficients for extreme temperatures on the probability to report a loss of energy become significant on conventional levels and relatively larger. Moreover, we observe that the shorter the period considered, the greater the impact of an additional summer day or hot day on concentration difficulties.

Since we know the exact date for all telephone interviews, we additionally draw on questions about insomnia and loss of energy from the telephone interview to check for robustness. The questions now refer to the last 30 days before the telephone interview. Again, we examine the impact of temperature exposure within the aforementioned 30-day period, as well as within a shorter 7-day time frame in order to account for any potential recall bias. Results in the Table C.8 confirm the previously found trend that both insomnia and loss of energy are increasing with higher temperature.[33]

We note that we interpret these effects as mechanisms only with caution. Two channels are possible. First, temperatures worsen the health status, possibly leading to more workplace accidents. This would imply that worsening health status acts as a possible mechanism. Second, temperature increases occupational accidents, which leads to worsening health status. This would imply that the deterioration of health status is a result of workplace accidents. However, we consider the first channel more likely, as we do not find significant effects on health outcomes on ice days, although the number of occupational accidents increases as well.

To further support our finding that insufficient sleep on hot days might act as a mechanism behind our results, we estimate equation (1) and add temperature bins containing the daily minimum temperature. If sleep acts as an important mechanism, then conditions during

[32]Due to the partially imputed survey date, we do not consider periods closer than 7 days to the survey date.

[33]Since there is no question on concentration difficulties in the telephone interview, we cannot provide robustness for this specific health outcome.

Table 5: Temperature and sleep quality

	(1)	(2)	(3)
	All	High risk	Low risk
< 0°C	0.052***	0.037***	0.065***
	(0.006)	(0.008)	(0.008)
25°C - 30°C	0.053***	0.052***	0.052***
	(0.005)	(0.006)	(0.006)
≥ 30°C	0.047***	0.051***	0.041***
	(0.007)	(0.009)	(0.009)
< -10°C	−0.004	−0.024**	0.009
	(0.007)	(0.010)	(0.008)
15°C - 20°C	0.044***	0.039***	0.050***
	(0.005)	(0.006)	(0.007)
≥ 20°C	0.052***	0.026	0.067***
	(0.012)	(0.024)	(0.014)
Num. Obs.	727 578	727 578	727 578
Pseudo R2	0.685	0.525	0.653
Zipcode2 x Week FE	X	X	X
Zipcode1 x Year x Month FE	X	X	X
Day of Week FE	X	X	X
Holiday FE	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses are clustered at the region-year level. (T) refers to daily maximum temperature and (Tmin) refers to daily minimum temperature. *p<0.1; **p<0.05; ***p<0.01.

night time should influence workplace accidents more than conditions during working hours. Hence, we would expect that an increase in daily minimum temperature, while controlling for daily maximum temperature, affects workplace accidents relatively more strongly than an increase in maximum temperature (Mullins & White, 2019). The results are presented in Table 5. Column (1) shows the results for all industries. We find that a cold night (day with minimum temperature < -10°C) does not have an effect on the workplace accidents, while hot nights (day with minimum temperature > 20°C) significantly increase workplace accidents by up to 5.2 percent. This indicates that hot nights affect sleep quality, leading to potentially a higher number of workplace accidents the next workday. Looking separately at high- and low-risk workers, the results suggest that for high-risk workers, high daytime temperatures affect workplace accidents relatively more than high nighttime temperatures. In contrast, for low-risk workers, high nighttime temperatures appear to affect occupational accidents relatively more. Overall, the results suggest that sleep is an important mechanism for the relationship between hot days and workplace accidents, in particular for workers in low-risk industries.

In addition, the data from the SHS allow us to study whether temperature changes a specific form of self-reported health-related behavior, alcohol consumption. Table 6 shows the impact of temperature on the probability to report alcohol consumption in the 7 days preceding the

Table 6: Temperature and alcohol consumption - telephone survey

	(1)	(2)	(3)	(4)
	All	Beer	Wine	Liquor
<0°C	0.001	−0.004	0.005*	0.000
	(0.003)	(0.003)	(0.003)	(0.003)
0°C - 5°C	0.001	−0.002	0.003	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
5°C - 10°C	0.002	0.003	0.003*	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
15°C - 20°C	0.001	0.002	−0.001	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
20°C - 25°C	0.003	0.005**	0.000	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)
25°C - 30°C	0.005**	0.010***	0.000	0.000
	(0.002)	(0.003)	(0.003)	(0.003)
≥ 30°C	0.002	0.010**	−0.002	−0.003
	(0.004)	(0.005)	(0.005)	(0.004)
Num.Obs.	65 931	65 745	65 794	65 789
R2 Adj.	0.044	0.185	0.126	0.035
Canton x Month FE	X	X	X	X
Year x Month FE	X	X	X	X
Day of Week FE	X	X	X	X
Holiday FE	X	X	X	X

Notes: The sample period is 1992 to 2017. Standard errors in parentheses are clustered at the canton-year level. *p<0.1; **p<0.05; ***p<0.01.

telephone interview. We find that the probability to consume alcohol increases with temperature, though the effect is small compared to the baseline probability of 82%. Our results suggest that in particular the probability to consume beer is affected. An additional hot day in the last 7 days increases the probability to report the consumption of beer by 1 p.p., which is a 2.2% increase relative to the baseline probability of 44%. In contrast, the probability to report the consumption of wine in the last 7 days preceding the telephone interview is decreasing with temperature. Exposure to extreme temperatures does not significantly affect the consumption behavior of high-proof alcohol.

Overall, it appears that both direct physiological effects and indirect effects, e.g., through impaired cognitive performance, may result in an increase in occupational accidents on days with extreme temperatures. We find that the number of workplace accidents due to slipping increases significantly on ice days. In addition, results from the SHS suggest that ice days do not lead to concentration difficulties, energy loss, or sleep problems. This suggests that workplace accidents due to ice days are due to a direct physiological effect rather than indirect effects. One possible reason is that ice days could affect fine motor skills, making slipping more likely. For hot days, the cause of accidents is not so clear. We find that there is a large positive, but insignificant increase in accidents due to self-overloading, indicating the role of direct physiological effects. However, we also find a significant increase in the number of accidents that are due to bumping against something, suggesting an indirect pathway.

Combining this with the findings from the SHS supports the indirect channel, as we find a higher probability of reporting sleep problems and loss of energy on hot days as well as a change in a specific health-related behavior, which in turn could lead to more workplace accidents.

7 Adaptation of Labor Supply

In a next step, we study workers' labor supply response to exposure to extreme temperatures. It is possible that workers gaining disutility from working in extreme temperature adapt their labor supply in response to temperatures (e.g., fewer working hours on construction sites on hot days) (Graff Zivin & Neidell, 2014; Garg et al., 2020; Rode et al., 2022). This is relevant for the interpretation of our main results (Graff Zivin & Neidell, 2013). For example, when workers decrease their labor supply in response to extreme temperatures, the prior found impact of temperature on workplace accidents is a lower bound, because the time the workers are exposed to temperatures at work decreases compared to a mid-temperature day.

To examine workers‘ labor supply responses we use the Swiss Labor Force Survey. The survey includes questions on whether a person has worked in the past week, the actual working hours in the past week, and reasons for working more or less. To analyse the impact of temperatures on the labor supply of workers, we model the number of hours worked by individual workers in the past week as a function of maximum temperatures, other contemporaneous environmental factors, worker characteristics, and a rich set of fixed effects. Our estimation equation reads as follows:

$$\text{Hours worked}_{nit} = \sum_{j \in J \setminus \{10-15\}} \beta^j \mathrm{T}^j_{it} + W'_{it}\gamma + X'_{nit}\theta + \mu_{im} + \delta_{my} + \delta_t + \epsilon_{nit}, \qquad (4)$$

where the dependent variable represents the actual number of hours worked of individual n residing in district i at week t. As the work-related questions we use refer to the week before the interview, T^j_{it} now contain the number of days in the week prior to the interview that fall in the jth temperature band. We omit the bin with the number of days in a given week with maximum daily temperatures larger than 10°C but equal to or less than 15°C. To control for individual-level determinants of labor supply we include a vector, X_{nit}, that controls for demographic characteristics and job characteristics of workers. More specifically, we include age, age-squared, gender, marital status, place of birth, level of education (ISCED), major occupation (ISCO), full-time/part-time, and the degree of urbanisation.[34] W_{it} is a vector of

[34] See Table C.2 in the Appendix for a summary of the individual-level covariates.

Table 7: Temperature and labor supply

	(1)	(2)	(3)
	All	High risk	Low risk
$< 0°C$	-0.018	-0.123^{**}	0.008
	(0.034)	(0.060)	(0.037)
0°C - 5°C	-0.016	-0.046	-0.006
	(0.023)	(0.042)	(0.026)
5°C - 10°C	-0.022	-0.048	-0.012
	(0.024)	(0.040)	(0.026)
15°C - 20°C	-0.012	-0.005	-0.010
	(0.025)	(0.046)	(0.029)
20°C - 25°C	-0.045	-0.113^{*}	-0.027
	(0.032)	(0.061)	(0.036)
25°C - 30°C	-0.082^{*}	-0.124	-0.070
	(0.042)	(0.088)	(0.044)
$\geq 30°C$	-0.195^{***}	-0.307^{**}	-0.172^{**}
	(0.068)	(0.127)	(0.072)
Num.Obs.	418 039	84 277	333 762
R2 Adj.	0.406	0.345	0.410
District x Month FE	X	X	X
Year x Month FE	X	X	X
Day of Week FE	X	X	X
Holiday FE	X	X	X

Notes: The dependent variable is the number of hours worked last week. The sample period is 2010 to 2019. Standard errors in parentheses are clustered at the canton-year level. *p<0.1; **p<0.05; ***p<0.01.

covariates that controls for weekly district level precipitation intensity, wind strength, and solar radiation. The model includes a full set of district-by-month fixed effects, μ_{im}, year-month fixed effects, δ_{my}, and indicators for the weekday of the interview and the number of holidays in the respective week, δ_t. Standard errors are clustered at the canton-year level. To test for potential differences in labor supply responses between workers in high-weather-exposed and low-weather-exposed sectors, we first run the regression for the entire sample and then for a subset of high and low-risk workers separately.

Table 7 shows that labor supply adaption to extreme temperatures is rather limited for most workers, however, the labor supply reduction in response to hot temperatures is nearly twice as large for high-risk workers compared to low-risk workers. In column (1), we uncover a non-linear relationship between exposure to temperatures and weekly hours worked for all industries. While an additional ice day does not impact weekly hours worked, an additional hot day significantly decreases weekly hours worked by 0.2, or 12 minutes, relative to a day in the omitted category. The estimates are not large in magnitudes, suggesting that on net labor supply is not highly responsive to temperatures. The results may conceal important heterogeneity due to differences in exposure to workplace temperatures. In column (2) we present the results for workers in high-risk industries only. The result suggests a U-shaped relationship between temperatures and labor supply for workers in industries with high-weather exposure. Our findings show that they reduce their weekly hours worked by 0.12 hours or 7 minutes due to an additional day with low temperatures. An additional hot day reduces the weekly labor supply of workers in high-risk industries by 0.31 hours, or 19 minutes, compared to a day in the mid-temperature category. In column (3) we present the results for workers in low-risk industries only. As for the full sample, we find that the estimated coefficient for ice days is close to zero and statistically insignificant. An additional hot day decreases the weekly labor supply of workers in low-risk industries by 0.17 hours, or 10 minutes, compared to a day in the mid-temperature category. This suggests that the labor supply response of high-risk workers to hot days is nearly twice as large. Put differently, a workweek with five hot days results in a decrease in weekly labor supply of about 1.5 hours for high-risk workers. This corresponds to a decrease in weekly labor supply of 5.1% compared to the average 31-hour workweek. For low-risk workers, the weekly labor supply decreases by 50 minutes, or 2.7%. Without labor supply adaption to extreme temperatures, the effect of an additional hot day on workplace accidents might even be larger for high-risk workers. In contrast, low-exposed workers only slightly reduce their labor supply on hot days and do not adapt their time allocated to work on ice days, even though extreme temperatures have a negative impact on their occupational health.

To test for robustness of our findings, we additionally estimate labor supply responses to temperatures using different sets of fixed effects in Table C.9 in the Appendix. The results are qualitatively similar to those of our main specification.

Our findings are mostly in line with the recent literature on the causal effect of temperatures on labor supply (Graff Zivin & Neidell, 2014; Garg et al., 2020; Rode et al., 2022). For example, Rode et al. (2022) find that relative to a moderate temperature day, an additional weekday with a maximum temperature of 40°C leads to a reduction in weekly minutes worked per high-risk worker by 29 minutes, while low-risk workers respond little.

8 Magnitude and Costs of Temperature-Induced Workplace Accidents

Next, we calculate the average yearly number of the additional temperature-related workplace accidents, and the resulting costs. To determine the number of additional workplace accidents caused solely by extreme temperatures, we multiply the coefficients of the temperature bins above 25°C and below 0°C from our preferred specification (Table 1, column

(5)) by the daily average number of occupational accidents per reference bin in a given year. Then we multiply this estimate by the average number of days per year in the respective temperature intervals in Switzerland. Aggregating the intervals results in an additional number of about 1,800 heat-related occupational accidents and about 800 cold-related accidents per year, which together account for slightly more than 1 percent of all reported accidents in Switzerland. Estimates of values per statistical injury (VSI) in Switzerland vary depending on the estimation approach between CHF 167,000, CHF 23,000 and CHF 1,350 per severe, moderate and mild case, respectively (Rheinberger et al., 2018) or CHF 35,000 on average (Kuhn & Ruf, 2013).[35] Our results imply that the additional 1,800 heat-related workplace accidents result in yearly costs of approximately CHF 63 million on average in Switzerland. Additional costs for 800 cold-related occupational accidents amount to 28 million CHF.[36]

Next, we approximate the number and costs of workplace accidents due to exposure to extreme temperature at the end of the 21st century. We base the climate change projections on the Hadley Centre Global Environment Model version 2 (HadGEM2) linked to the Royal Netherlands Meteorological Institute (KNMI) regional climate model RACMO22E. We predict the expected number of additional temperature-related occupational accidents under the three different climate change scenarios, namely unabated emissions (RCP 8.5), non-compliant mitigation (RCP 4.5) and compliant mitigation (RCP 2.6). We note that these estimates should be interpreted with caution as they (i) are likely to be an overestimate as they do not take climate change adaption into account, (ii) do not consider changes in the overall number and composition of the labor force. To calculate the additional number and costs of future temperature-related workplace accidents, we proceed similarly to the previous back-of-the-envelope calculation. We again multiply the coefficients of the temperature bins above 25°C and below 0°C from our preferred specification by the daily average number of workplace accidents per reference bin in a given year. We then multiply this estimate by the difference in the average number of ice, summer, and hot days per year in Switzerland between the observed period (1996-2019) and the end-of-century period (2070-2099). The results show that by the end of the 21st century, there will be an estimated 490 to 2,705 additional heat-related and 202 to 653 fewer cold-related occupational accidents per year under the RCP 2.6 and 8.5 scenarios, respectively. The increase in the number of heat-related occupational accidents is partially offset by the decrease in the number of cold-related accidents, especially in the RCP 2.6 scenario. Total cost of the additional temperature-related

[35]For the back-of-the-envelope welfare calculations we refer to the VSI as calculated in Kuhn & Ruf (2013).

[36]See Tables C.10 and C.11 in the Appendix for more details regarding the calculation.

accidents will approximately amount to CHF 10 million to CHF 72 million per year at the end of the century, depending on mitigated emissions. See Table C.12 in the Appendix for more details regarding the calculation.

9 Conclusion

This paper studies the impact of exposure to extreme temperature on occupational safety in Switzerland. The results show that even in temperate climate zones, like Switzerland, high temperatures lead to an increase in workplace accidents by up to 7.4 percent. Regardless of demographic characteristics and income, workers seem to be equally affected by an increase in occupational accidents due to an additional hot day. On ice days, the number of workplace accidents increases on average by 6.3 percent, with older employees and employees in industries with low-weather exposure affected more. Our results suggest that insomnia may be a mechanism underlying the relationship between workplace accidents and hot temperatures, especially for workers in industries with low-weather exposure. The primary cause for the increase in workplace accidents on ice days is slipping of workers. While extreme temperatures lead to deterioration in worker health, we only observe limited labor supply adjustment to extreme temperatures for most workers. However, workers in high-exposed industries decrease their weekly labor supply by 19 minutes due to an additional hot day, which is nearly twice as much as for low-risk workers. The additional number of heat-related accidents is 1,800, and the additional number of cold-related accident is 800. The associated costs amount to 63 million for accidents on summer and hot days, and to CHF 28 million for accidents on ice days, for a total of CHF 91 million. According to our climate change predictions scenarios, the costs for temperature-induced workplace accidents will further increase to as much as CHF 163 million per year by the end of the century. These findings show how important it is for workplace safety to adapt to suboptimal temperature exposure and take preventive measures. With more air-conditioned workplaces, worker protection laws, and rescheduling work hours to avoid temperature extremes during the workday, countries could adapt to suboptimal temperatures. Moreover, it is crucial that policy makers correct carbon externalities. The medical expenses and lost working time due to temperature induced occupational accidents incur high costs. The social costs of carbon (SCC) will be underestimated if its calculation does not account for the impact of sub-optimal temperature on occupational safety (Park et al., 2021).

References

Alhola, P., & Polo-Kantola, P. (2007). Sleep deprivation: Impact on cognitive performance. *Neuropsychiatric Disease and Treatment*, *3*(5), 553–567.

Almås, I., Auffhammer, M., Bold, T., Bolliger, I., Dembo, A., Hsiang, S. M., ... Pickmans, R. (2019). *Destructive behavior, judgment, and economic decision-making under thermal stress* (Tech. Rep.). National Bureau of Economic Research.

Andrews, O., Le Quéré, C., Kjellstrom, T., Lemke, B., & Haines, A. (2018). Implications for workability and survivability in populations exposed to extreme heat under climate change: a modelling study. *The Lancet Planetary Health*, *2*(12), e540–e547.

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016). Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. *Journal of Political Economy*, *124*(1), 105–159.

Baylis, P. (2020). Temperature and temperament: Evidence from Twitter. *Journal of Public Economics*, *184*, 104161.

BLS. (2020). National census of fatal occupational injuries in 2020. *Washington, DC: Bureau of Labor Statistics*.

Boden, L. I., & Ozonoff, A. (2008). Capture–recapture estimates of nonfatal workplace injuries and illnesses. *Annals of Epidemiology*, *18*(6), 500–506.

Boone, J., & Van Ours, J. C. (2006). Are recessions good for workplace safety? *Journal of Health Economics*, *25*(6), 1069–1093.

Boone, J., Van Ours, J. C., Wuellrich, J.-P., & Zweimüller, J. (2011). Recessions are bad for workplace safety. *Journal of Health Economics*, *30*(4), 764–773.

Burgess, R., Deschenes, O., Donaldson, D., & Greenstone, M. (2017). Weather, climate change and death in India. *University of Chicago*.

CH2018, C. (2018). *Climate scenarios for Switzerland.* National Centre for Climate Services Zurich.

Charles, K. K., Johnson, M. S., Stephens Jr, M., & Lee, D. Q. (2022). Demand conditions and worker safety: Evidence from price shocks in mining. *Journal of Labor Economics*, *40*(1), 47–94.

Choi, B. C., & Pak, A. W. (2005). A catalog of biases in questionnaires. *Preventing Chronic Disease*, *2*.

Cohn, J. B., & Wardlaw, M. I. (2016). Financing constraints and workplace safety. *The Journal of Finance*, *71*(5), 2017–2058.

Colmer, J. (2021). Temperature, labor reallocation, and industrial production: Evidence from India. *American Economic Journal: Applied Economics*, *13*(4), 101–24.

Conley, T. G. (1999). GMM estimation with cross sectional dependence. *Journal of Econometrics*, *92*(1), 1–45.

Curci, G., Depalo, D., & Palma, A. (2023). The dirtier you breathe, the less safe you are. The effect of air pollution on work accidents.

Dell, M., Jones, B. F., & Olken, B. A. (2014). What do we learn from the weather? The new climate-economy literature. *Journal of Economic Literature*, *52*(3), 740–798.

Deschênes, O., & Greenstone, M. (2011). Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the US. *American Economic Journal: Applied Economics*, *3*(4), 152–85.

Deschenes, O., & Moretti, E. (2009). Extreme weather events, mortality, and migration. *The Review of Economics and Statistics*, *91*(4), 659–681.

Dillender, M. (2021). Climate change and occupational health are there limits to our ability to adapt? *Journal of Human Resources*, *56*(1), 184–224.

Dillender, M., & McInerney, M. (2020). The role of Mexican immigration to the United States in improved workplace safety for natives from 1980 to 2015. *Journal of Health Economics*, *70*, 102280.

EU-OSHA. (2017). An international comparison of the cost of work-related accidents and illnesses. *European Agency for Safety and Health at Work*.

EU-OSHA. (2022). *About EU-OSHA - National focal points: Switzerland.* Retrieved from https://osha.europa.eu/en/about-eu-osha/national-focal-points/switzerland (accessed 30.11.2022)

EU-OSHA. (2019). Third European survey of enterprises on new and emerging risks (ESENER-3). *European Agency for Safety and Health at Work*.

Eurofound. (2015). Sixth European working conditions survey 2015.

Eurostat. (2013). European statistics on accidents at work (esaw)-summary methodology. *Eurostat Methodologies&Working Paper*.

Eurostat. (2019). Accidents at work statistics.

Filomena, M., & Picchio, M. (2023). Unsafe temperatures, unsafe jobs: The impact of weather conditions on work-related injuries. *IZA Discussion Paper No. 16169*.

Garg, T., Gibson, M., & Sun, F. (2020). Extreme temperatures and time use in China. *Journal of Economic Behavior & Organization*, *180*, 309–324.

Graff Zivin, J., Hsiang, S. M., & Neidell, M. (2018). Temperature and human capital in the short and long run. *Journal of the Association of Environmental and Resource Economists*, *5*(1), 77–105.

Graff Zivin, J., & Neidell, M. (2013). Environment, health, and human capital. *Journal of Economic Literature*, *51*(3), 689–730.

Graff Zivin, J., & Neidell, M. (2014). Temperature and the allocation of time: Implications for climate change. *Journal of Labor Economics*, *32*(1), 1–26.

Hämäläinen, P., Takala, J., & Saarela, K. L. (2006). Global estimates of occupational accidents. *Safety Science*, *44*(2), 137–156.

Hsiang, S. (2016). Climate econometrics. *Annual Review of Resource Economics*, *8*, 43–75.

IEA. (2018). The future of cooling: Opportunities for energy-efficient air conditioning. *International Energy Agency*.

ILO. (2022). *Statistics on health and safety at work.* Retrieved from https://ilostat.ilo.org/topics/safety-and-health-at-work/# (accessed 09.12.2022)

IPCC. (2021). Summary for policymakers. In *Climate change 2021: The physical science basis. contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change.* Cambridge University Press.

Ireland, A., Johnston, D., & Knott, R. (2023). Heat and worker health. *arXiv preprint arXiv:2301.11554*.

Jessoe, K., Manning, D. T., & Taylor, J. E. (2018). Climate change and labour allocation in rural Mexico: Evidence from annual fluctuations in weather. *The Economic Journal*, *128*(608), 230–261.

Joe, L., Roisman, R., Beckman, S., Jones, M., Beckman, J., Frederick, M., & Harrison, R. (2014). Using multiple data sets for public health tracking of work-related injuries and illnesses in California. *American Journal of Industrial Medicine*, *57*(10), 1110–1119.

Johnson, M. S. (2020). Regulation by shaming: Deterrence effects of publicizing violations of workplace safety and health laws. *American Economic Review*, *110*(6), 1866–1904.

Johnson, M. S., Levine, D. I., & Toffel, M. W. (2022). Improving regulatory effectiveness through better targeting: Evidence from OSHA. *American Economic Journal: Applied Economics*, forthcoming.

Kuhn, A., & Ruf, O. (2013). The value of a statistical injury: New evidence from the Swiss labor market. *Swiss Journal of Economics and Statistics*, *149*(1), 57–86.

Kurppa, K. (2015). Severe under-reporting of work injuries in many countries of the Baltic sea region: An exploratory semi-quantitative study. *Helsinki: Finnish Institute of Occupational Health*.

Lavy, V., Rachkovski, G., & Yoresh, O. (2022). *Heads up: Does air pollution cause workplace accidents?* (Tech. Rep.). National Bureau of Economic Research.

LoPalo, M. (2023). Temperature, worker productivity, and adaptation: Evidence from survey data production. *American Economic Journal: Applied Economics*, *15*(1), 192–229.

McManus, T. C., & Schaur, G. (2016). The effects of import competition on worker health. *Journal of International Economics*, *102*, 160–172.

Mullins, J. T., & White, C. (2019). Temperature and mental health: Evidence from the spectrum of mental health outcomes. *Journal of Health Economics*, *68*, 102240.

Obradovich, N., Migliorini, R., Mednick, S. C., & Fowler, J. H. (2017). Nighttime temperature and human sleep loss in a changing climate. *Science Advances*, *3*(5), e1601555.

OECD. (2023). *Exchange rates (indicator).* Retrieved from https://data.oecd.org/conversion/exchange-rates.htm (accessed 13.06.2023)

Park, J. (2020). Hot temperature and high stakes performance. *Journal of Human Resources*, *57*(2), 400–434.

Park, J., Goodman, J., Hurwitz, M., & Smith, J. (2020). Heat and learning. *American Economic Journal: Economic Policy*, *12*(2), 306–39.

Park, J., Pankratz, N., & Behrer, A. (2021). Temperature, workplace safety, and labor market inequality. *IZA Discussion Paper No. 14560*.

Randazzo, T., De Cian, E., & Mistry, M. N. (2020). Air conditioning and electricity expenditure: The role of climate in temperate countries. *Economic Modelling*, *90*, 273–287.

Rheinberger, C. M., Schläpfer, F., & Lobsiger, M. (2018). A novel approach to estimating the demand value of public safety. *Journal of Environmental Economics and Management*, *89*, 285–305.

Rode, A., Baker, R. E., Carleton, T., D'Agostino, A., Delgado, M., Foreman, T., ... others (2022). Labor disutility in a warmer world: The impact of climate change on the global workforce.

Rousi, E., Kornhuber, K., Beobide-Arsuaga, G., Luo, F., & Coumou, D. (2022). Accelerated Western European heatwave trends linked to more-persistent double jets over Eurasia. *Nature Communications*, *13*(1), 1–11.

SECO. (2022). *Gesundheitsschutz am Arbeitsplatz: Klima (Behaglichkeit, Hitze, Wärmestrahlung, Kälte, UV).* Retrieved from https://www.seco.admin.ch/seco/de/home/Arbeit/Arbeitsbedingungen/gesundheitsschutz-am-arbeitsplatz/Arbeitsraeume-und-Umgebungsfaktoren/Klima.html (accessed 30.11.2022)

Seltenrich, N. (2015). *Between extremes: Health effects of heat and cold.* National Institute of Environmental Health Sciences.

Sexton, S., Wang, Z., & Mullins, J. T. (2022). Heat adaptation and human performance in a warming climate. *Journal of the Association of Environmental and Resource Economists*, *9*(1), 141–163.

Somanathan, E., Somanathan, R., Sudarshan, A., & Tewari, M. (2021). The impact of temperature on productivity and labor supply: Evidence from Indian manufacturing. *Journal of Political Economy*, *129*(6), 1797–1827.

SSUV. (2020). *Unfallstatistik UVG 2020.* Luzern.

SSUV. (2021). *Unfallstatistik UVG 2021.* Luzern.

Tourangeau, R., Rips, L. J., & Rasinski, K. (2000). The psychology of survey response.

White, C. (2017). The dynamic relationship between temperature and morbidity. *Journal of the Association of Environmental and Resource Economists*, *4*(4), 1155–1198.

A Location of Workplace Accidents

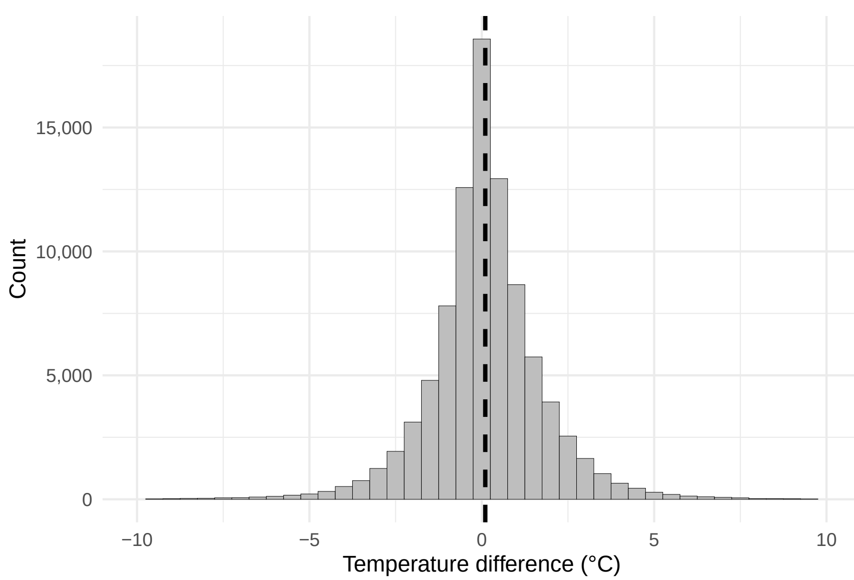
Table A.1: Comparison between accident locations in full sample and 5% sample

	A	BDE	C	F	GHI	J	K	L	MN	OPQ	RSTU	Total
Share in same zip code	0.779	0.713	0.820	0.611	0.628	0.468	0.566	0.643	0.477	0.767	0.653	0.675
Distance between zip codes (in km)	37.94	39.76	55.02	38.79	70.18	77.28	74.54	59.91	61.98	42.88	70.79	55.82

The census of occupational accidents in Switzerland does not include information on the actual location of the accident, but on the location of the injured party's employer. This might results in a mismatch between the location of the accident reported in the census and the location where the accident occurred, since, for example, some companies operating nationwide in Switzerland report accidents based on the location of their headquarters. For a more detailed analysis of occupational accidents in Switzerland, each year the SSUV randomly selects five percent of the observations from the population of all occupational accidents for which it identifies information on the cause of the accident and the zip code in which the accident occurred. We use this random sample to discuss how the discrepancy between accident locations might affect our results.

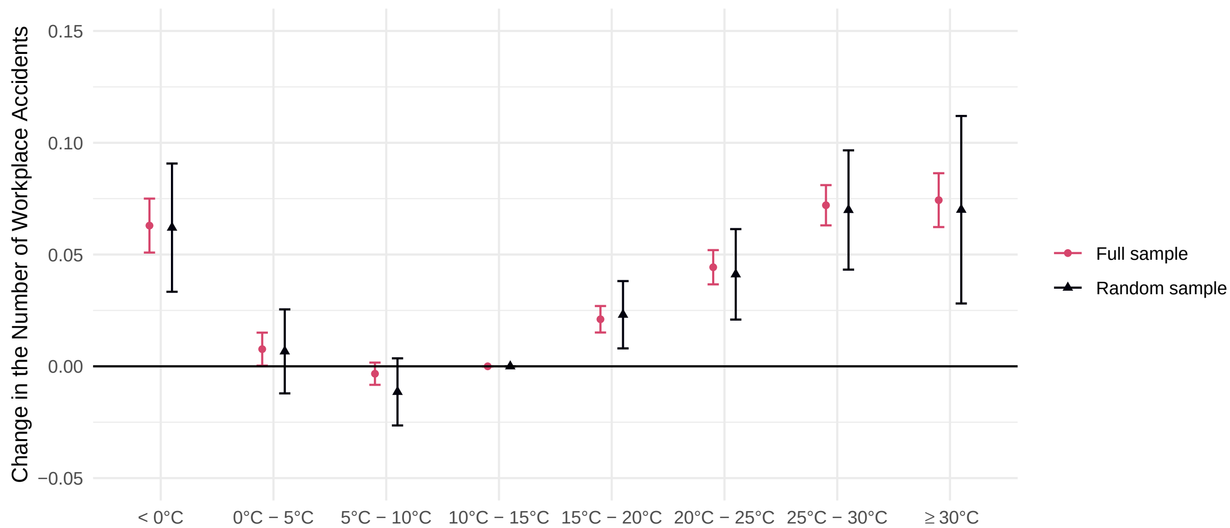
In Table A.1 we provide some measures to compare the actual accident location to the

Figure A.1: Distribution of differences in maximum daily temperature



Notes: This figure shows the distribution of the maximum daily temperature difference between actual accident locations and accident location as reported in the full sample. The dashed line indicates the respective sample mean

Figure A.2: Estimated relationship between daily count of workplace accidents and daily maximum temperature by sample



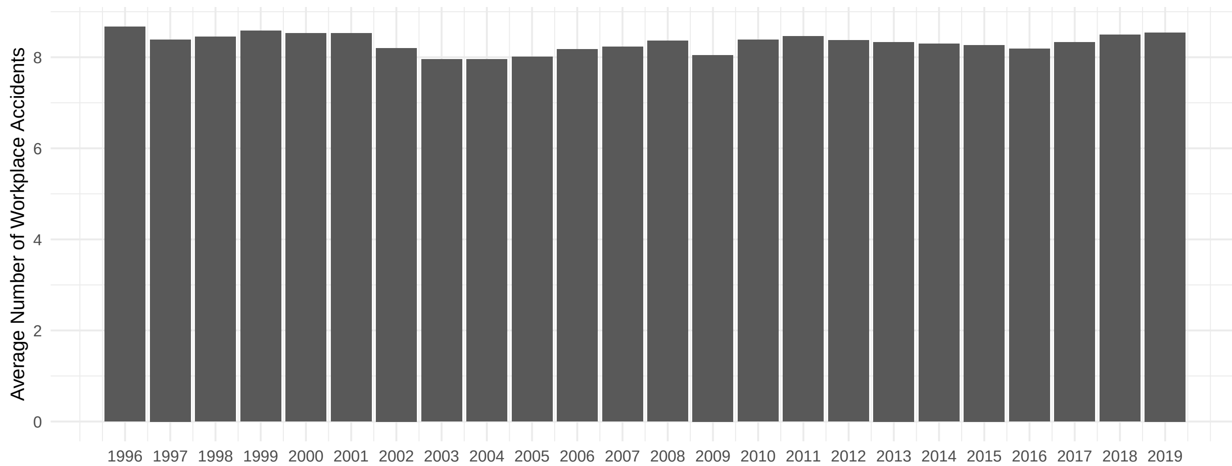
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by sample size. Coefficients are obtained by applying the full model in equation (1) to the respective subsample. Full sample refers to the universe of workplace accidents in Switzerland from 1996 to 2019. Random sample refers to the five percent random drawn from the full population of workplace accidents in Switzerland from 1996 to 2019. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

location reported in the full sample. We calculate the overlap between the zip code of the injured party's employer and the zip code where the accident occurred for the entire random sample and for each sector separately. Overall, 67.5 percent of the accidents in the random sample occurred in the same zip code as the zip code of the injured party's employer. The proportion varies widely by sector. 82.0 percent of accidents in manufacturing (C) occur in the same zip code as that of the employer, and only 46.8 percent of accident locations in information and communications (J) have the same zip code as the injured party's employer. Additionally, we calculate the average distance between the centroid of the zip code of the injured party‘s employer and the zip code of the actual accident location for all accidents were these locations do not match. Next, we check to what degree climatic conditions differ between reported and actual accident location. To do so, we compute the daily difference in maximum temperatures between accident locations where zip codes do not match. Figure A.1 plots the distribution of this temperature difference. The average difference in maximum temperatures between accidents where actual location and location of the injured party‘s employer are not the same is 0.10°C.

To test whether this discrepancy between zip codes affects our results, we estimate our baseline model presented in equation (1) for the random sample only, using environmental conditions for the actual accident location. Results are shown in Figure A.2. Magnitudes of the coefficients obtained for the random sample are similar to the magnitudes of the coefficients for the full sample. However, estimates are more imprecisely estimated than in the baseline model with the full data set, potentially due to the much smaller sample size. Therefore, we are confident that using the location of the injured party‘s employer in the full sample for temperature interpolation does not affect our results.

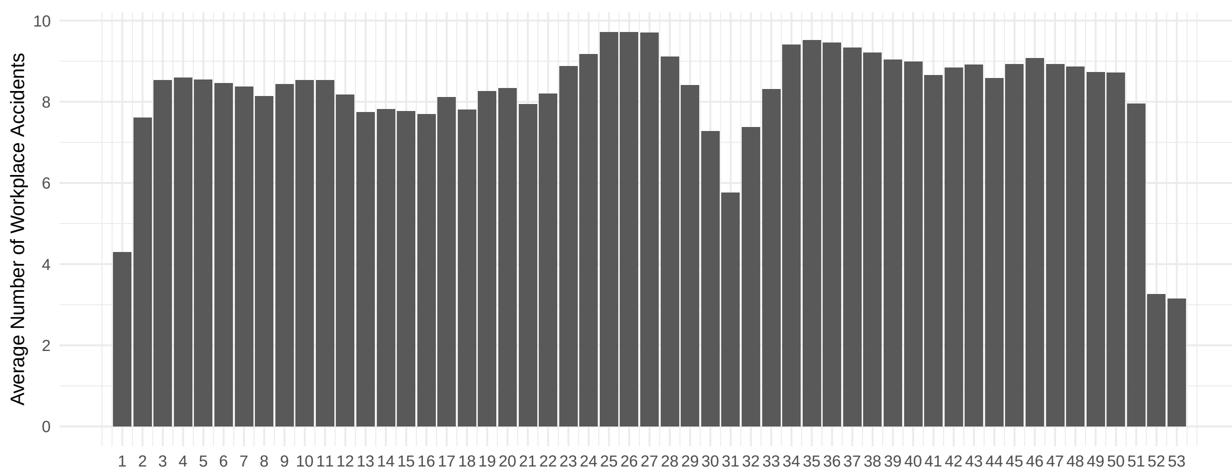
B Additional Figures

Figure B.1: Average daily number of workplace accidents per zip code by year, Switzerland, 1996 - 2019



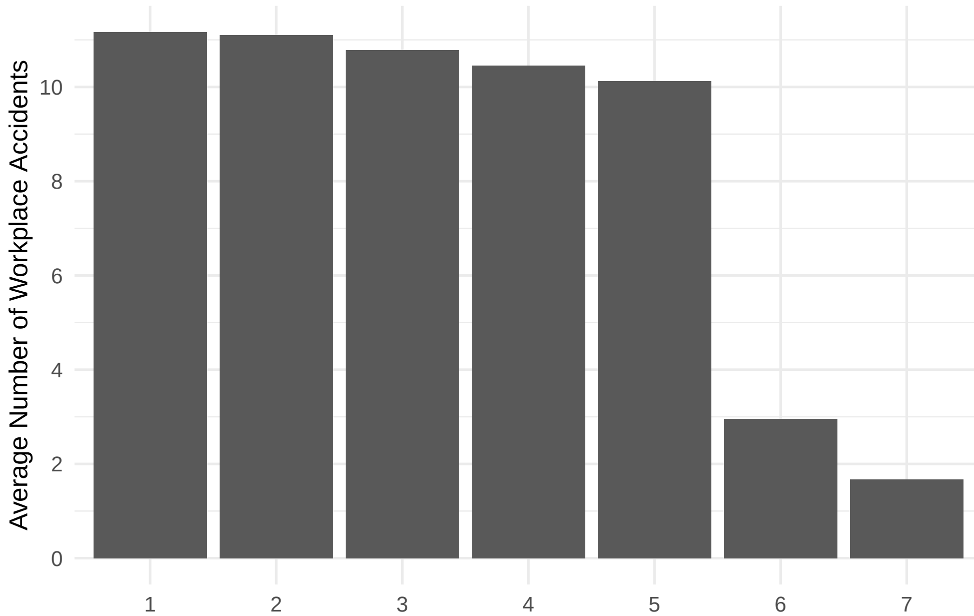
Notes: This figure shows the average daily number of workplace accidents per two-digit zip code by year in Switzerland from 1996 to 2019.

Figure B.2: Average daily number of workplace accidents per zip code by week of the year, Switzerland, 1996 - 2019



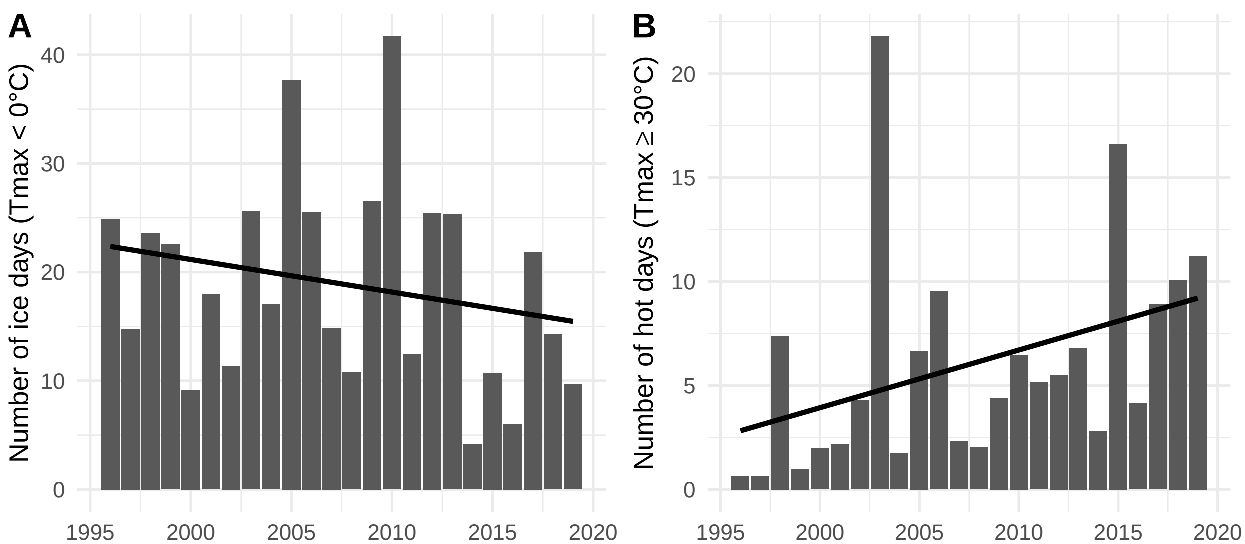
Notes: This figure shows the average daily number of workplace accidents per two-digit zip code by week of year in Switzerland from 1996 to 2019.

Figure B.3: Average daily number of workplace accidents per zip code by day of week, Switzerland, 1996 - 2019



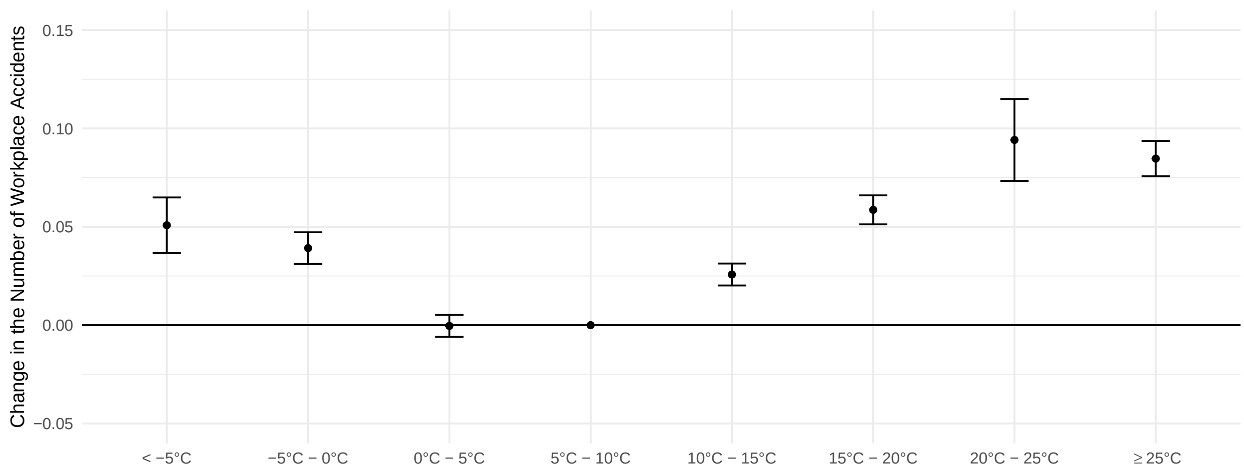
Notes: This figure shows the average daily number of workplace accidents per two-digit zip code by day of week in Switzerland from 1996 to 2019. 1: Monday, 2: Tuesday, 3: Wednesday, 4: Thursday, 5: Friday, 6: Saturday, 7: Sunday.

Figure B.4: Evolution of (A) ice days and (B) hot days in Switzerland, 1996 - 2019



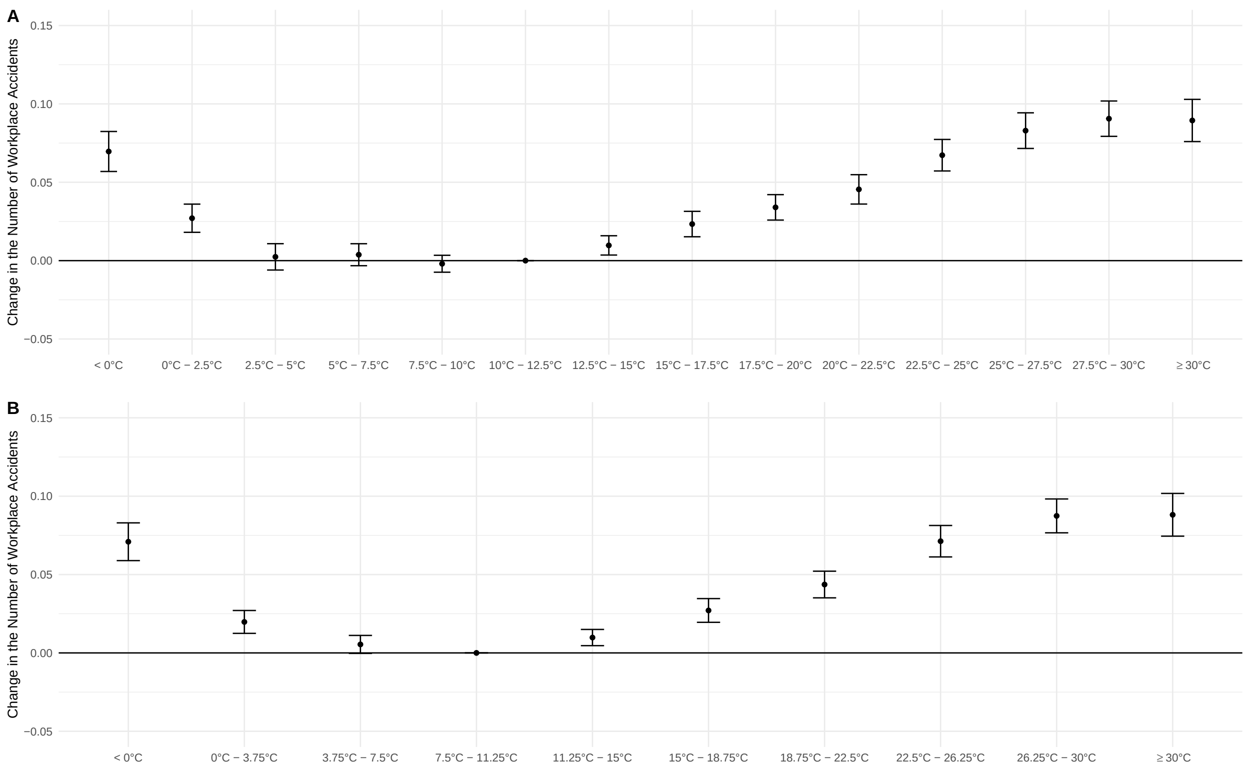
Notes: The left panel (A) shows the evolution of the average number of ice days (i.e., $T_{max} < 0$) in Switzerland from 1996 to 2019. The right panel (B) shows the evolution of the average number of hot days (i.e., $T_{max} \geq 30$) in Switzerland from 1996 to 2019.

Figure B.5: Estimated relationship between daily count of workplace accidents and daily mean temperature



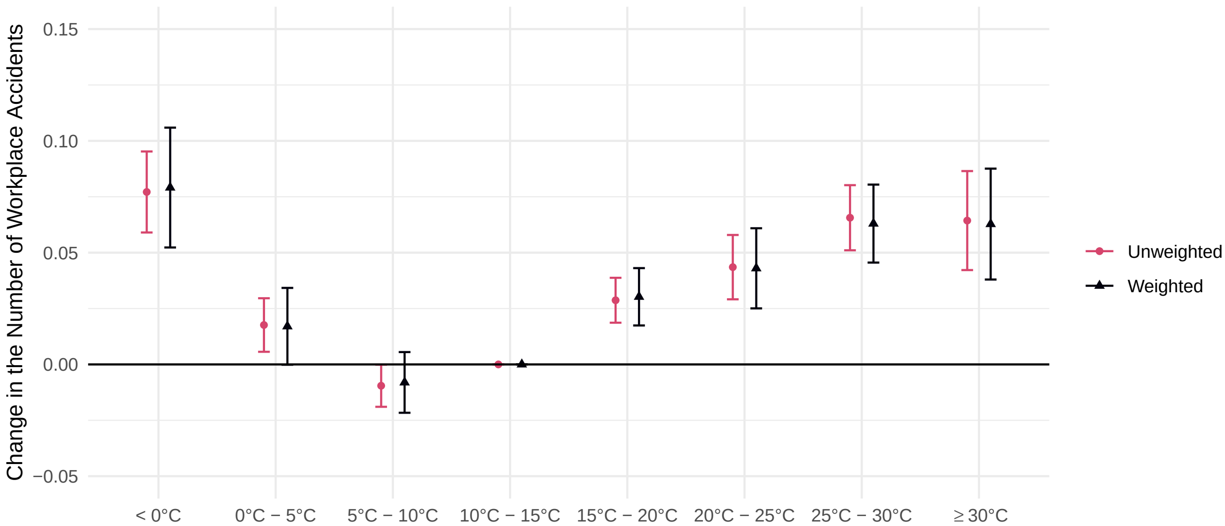
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily mean temperatures. Coefficients are obtained by applying the full model in equation (1), using 5-degree-temperature bins that include mean daily temperatures instead of maximum daily temperatures. The response function is normalized with the 5°C - 10°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with an average temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure B.6: Estimated relationship between daily count of workplace accidents and daily maximum temperature - different temperature bins



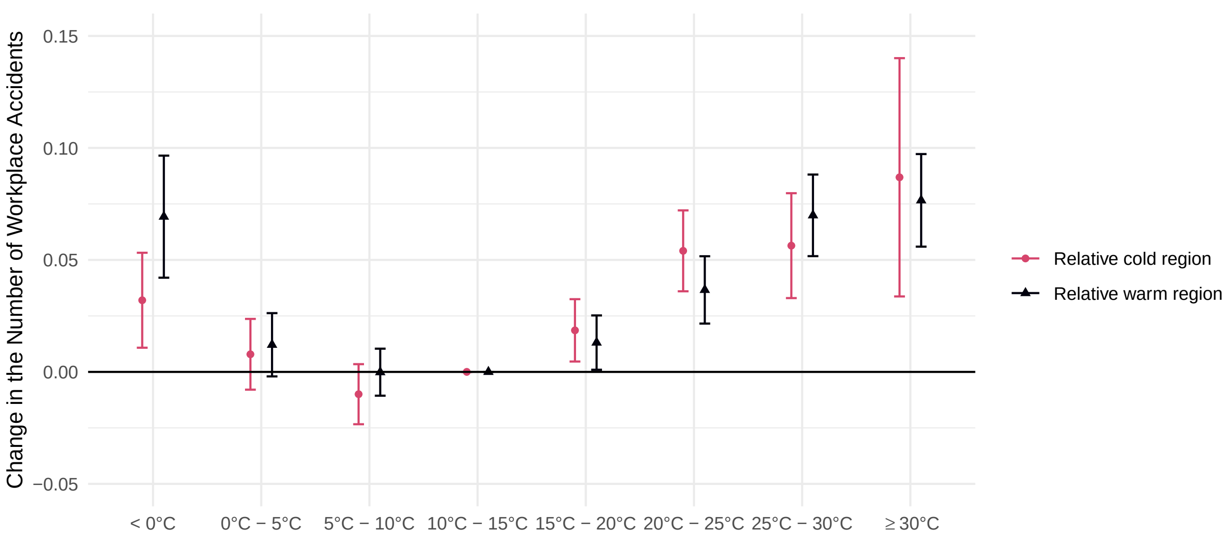
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by different temperature bins. Coefficients are obtained by applying the full model in equation (1), with temperature divided into 2.5-degree bins and 3.75-degree bins instead of five-degree bins. In Panel A the response function is normalized with the 10°C - 12.5°C category set equal to zero, in Panel B the response function is normalized with the 7.5°C - 11.25°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure B.7: Estimated relationship between daily count of workplace accidents and daily maximum temperature - weighted by full-time equivalents



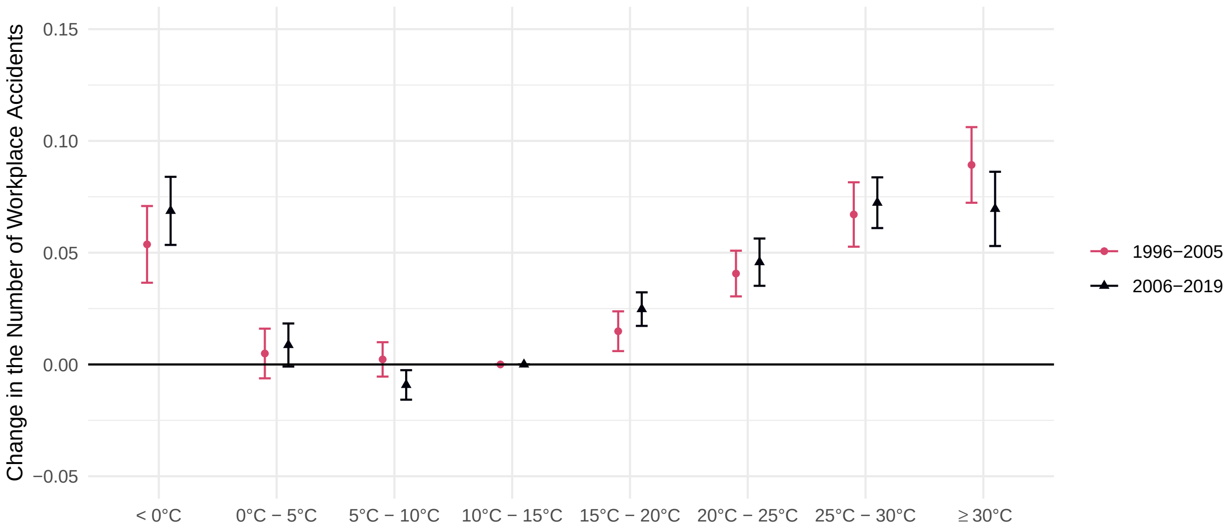
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures when weighted by the total number of full-time equivalents in a given zip code per year. The observation period is now 2011-2019. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure B.8: Estimated relationship between daily count of workplace accidents and daily maximum temperature by relative warm and cold regions



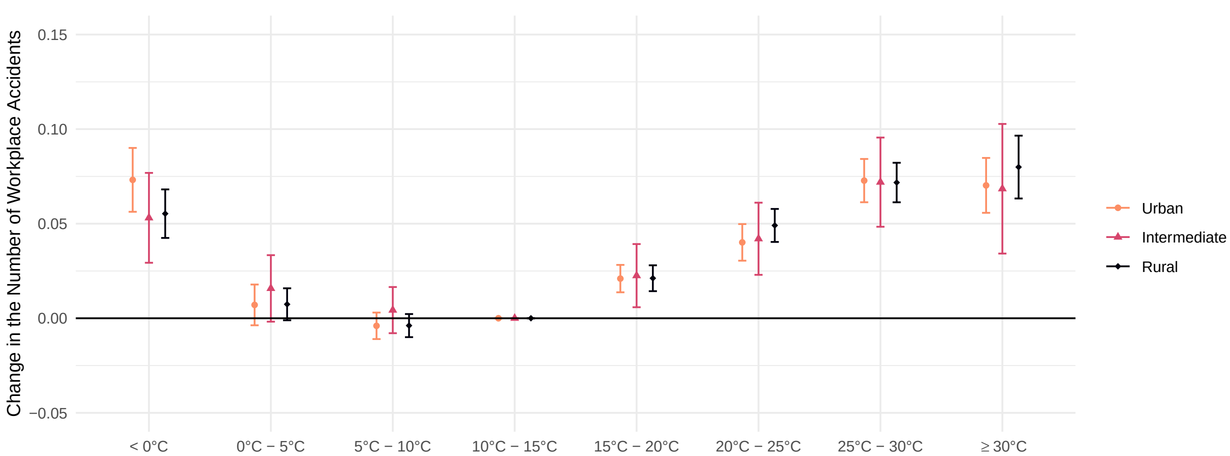
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by relative cold and warm zip codes. Coefficients are obtained by applying the full model in equation (1) to the respective subsample. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure B.9: Estimated relationship between daily count of workplace accidents and daily maximum temperature by time period



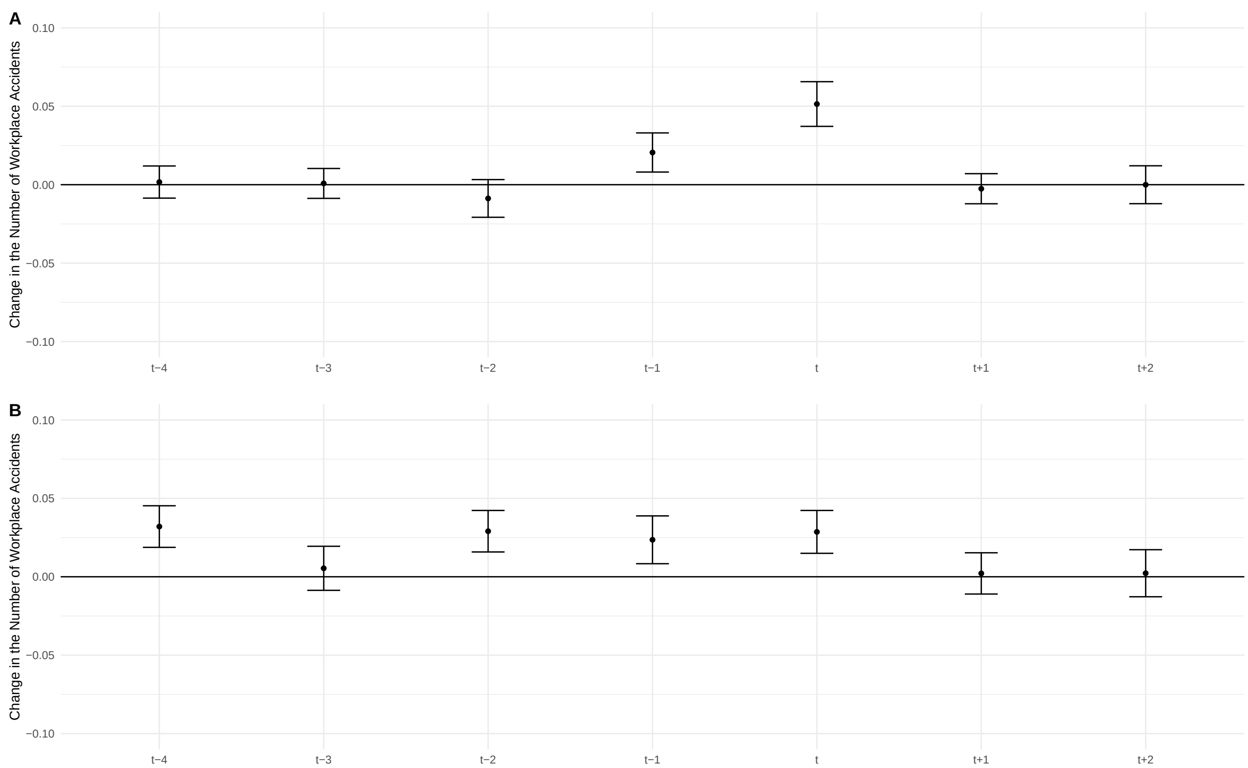
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by the periods 1996-2005 and 2006-2019. Coefficients are obtained by applying the full model in equation (1) to the respective subsample. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure B.10: Estimated relationship between daily count of workplace accidents and daily maximum temperature by degree of urbanisation



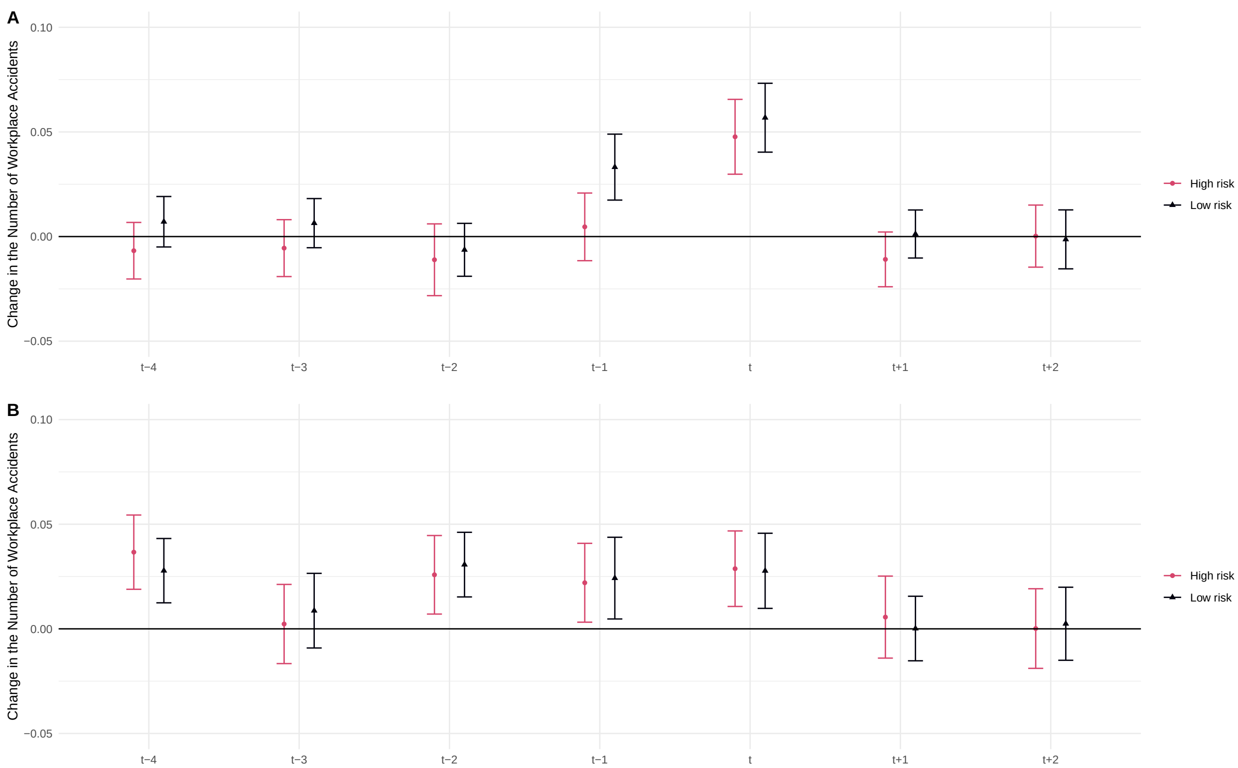
Notes: This figure illustrates the response function between the count of daily workplace accidents and daily maximum temperatures by the degree of urbanisation of the zip codes. Coefficients are obtained by applying the full model in equation (1) to the respective subsample. The response function is normalized with the 10°C - 15°C category set equal to zero. Each coefficient can be interpreted as the percentage change in the number of workplace accidents on a day in bin j relative to a day with a maximum temperature in the base category. Whiskers denote the obtained 95% confidence intervals.

Figure B.11: Estimated relationship between daily count of workplace accidents and daily maximum temperature - lagged temperatures



Notes: This figure illustrates the effect of temperature lags, on-the-day temperature and temperature leads on workplace accidents. Coefficients are obtained by applying the full model in equation (1), with temperature lags and leads. Panel A shows the coefficients of ice days, Panel B shows the coefficients of hot days, respectively. Whiskers denote the obtained 95% confidence intervals.

Figure B.12: Estimated relationship between daily count of workplace accidents and daily maximum temperature - lagged temperatures by industry



Notes: This figure illustrates the effect of temperature lags, on-the-day temperature and temperature leads on workplace accidents by industry. Coefficients are obtained by applying the full model in equation (1), with temperature lags and leads. Panel A shows the coefficients of ice days, Panel B shows the coefficients of hot days, respectively. Whiskers denote the obtained 95% confidence intervals.

C Additional Tables

Table C.1: Summary statistics of accident data

% Male	0.78
% Aged <30	0.36
% Aged 30-50	0.45
% Aged >50	0.19
% With compensation	0.41
% Severe	0.04
% Income -50,000	0.15
% Income 50,000-100,000	0.27
% Income 100,000+	0.02
% High-risk industries	0.44
% Low-risk industries	0.56

Table C.2: Summary statistics of survey data

	SLFS	SHS
% Male	0.51	0.47
Age	43.4	41.2
% Birthplace/Nationality Switzerland	0.59	0.82
% Married	0.55	0.54
% Densley urbanised	0.45	0.65
% Full-time	0.62	0.51
% University	0.31	0.25
% Skill level 2	0.47	-
% Skill level 3	0.15	-
% Skill level 4	0.38	-
Number of hours worked last week	35.13	-
Number of hours worked per contract	30.86	-
% Alcohol last 7 days	-	0.82
% Beer last 7 days	-	0.44
% Wine last 7 days	-	0.68
% Liquor last 7 days	-	0.22
% Insomnia last 14 days	-	0.70
% Loss of energy last 14 days	-	0.80
% Concentration difficulty last 14 days	-	0.61
% Insomnia last 30 days	-	0.33
% Loss of energy last 30 days	-	0.43

Table C.3: Average number of days by temperature bin, 2070-2099

	1996-2019	RCP 2.6	RCP 4.5	RCP 8.5
< 0°C	18.9	14.2	7.7	3.6
0°C - 5°C	51.0	40.0	29.4	21.3
5°C - 10°C	64.3	60.5	60.8	48.5
10°C - 15°C	64.6	64.8	70.6	68.4
15°C - 20°C	70.5	70.6	67.9	65.4
20°C - 25°C	59.0	61.8	62.0	61.1
25°C - 30°C	31.1	38.7	46.0	56.5
≥ 30°C	6.0	8.4	14.6	35.2

Table C.4: Estimated relationship between daily count of workplace accidents and daily maximum temperature - different estimation methods

	(1)	(2)	(3)
	PPML	IHS	OLS
< 0°C	0.063***	0.043***	0.440***
	(0.006)	(0.007)	(0.060)
0°C - 5°C	0.008**	0.002	0.055
	(0.004)	(0.005)	(0.043)
5°C - 10°C	−0.003	−0.005	−0.025
	(0.003)	(0.003)	(0.032)
15°C - 20°C	0.021***	0.023***	0.161***
	(0.003)	(0.004)	(0.038)
20°C - 25°C	0.044***	0.051***	0.416***
	(0.004)	(0.005)	(0.055)
25°C - 30°C	0.072***	0.082***	0.717***
	(0.005)	(0.006)	(0.065)
≥ 30°C	0.074***	0.079***	0.773***
	(0.006)	(0.009)	(0.089)
Num. Obs.	727 578	727 578	727 578
Pseudo R2/ R2 Adj.	0.685	0.799	0.774
Zipcode2 x Week FE	X	X	X
Zipcode1 x Year x Month FE	X	X	X
Day of Week FE	X	X	X
Holiday FE	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses are clustered at the region-year level. Column (1) displays our baseline results using PPML. Column (2) and (3) are estimated using OLS. Column (2) uses the IHS transformation of the number of workplace accidents as outcome variable and column (3) uses the raw count of the number of workplace accidents as outcome variable. *p<0.1; **p<0.05; ***p<0.01.

Table C.5: Estimated relationship between daily count of workplace accidents and daily maximum temperature - different level of clustering

	(1)	(2)	(3)	(4)	(5)	(6)
	Zipcode2	Zipcode1	Zipcode1 + Year x Month	Conley (50km)	Conley (100km)	Zipcode1 x Year
< 0°C	0.063***	0.063***	0.063***	0.063***	0.063***	0.063***
	(0.006)	(0.007)	(0.013)	(0.006)	(0.008)	(0.006)
0°C - 5°C	0.008**	0.008**	0.008	0.008**	0.008	0.008**
	(0.003)	(0.004)	(0.007)	(0.004)	(0.005)	(0.004)
5°C - 10°C	−0.003*	−0.003*	−0.003	−0.003*	−0.003**	−0.003
	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.003)
15°C - 20°C	0.021***	0.021***	0.021***	0.021***	0.021***	0.021***
	(0.002)	(0.002)	(0.005)	(0.002)	(0.001)	(0.003)
20°C - 25°C	0.044***	0.044***	0.044***	0.044***	0.044***	0.044***
	(0.003)	(0.003)	(0.007)	(0.002)	(0.002)	(0.004)
25°C - 30°C	0.072***	0.072***	0.072***	0.072***	0.072***	0.072***
	(0.003)	(0.003)	(0.008)	(0.002)	(0.002)	(0.005)
≥ 30°C	0.074***	0.074***	0.074***	0.074***	0.074***	0.074***
	(0.004)	(0.004)	(0.013)	(0.004)	(0.003)	(0.006)
Num.Obs.	727 578	727 578	727 578	727 578	727 578	727 578
Pseude R2	0.685	0.684	0.684	0.684	0.684	0.684
Zipcode2 x Week FE	X	X	X	X	X	X
Zipcode1 x Year x Month FE	X	X	X	X	X	X
Day of Week FE	X	X	X	X	X	X
Holiday FE	X	X	X	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses vary by column. Column (6) displays our baseline results where we cluster standard errors at the region-year level. *p<0.1; **p<0.05; ***p<0.01.

Table C.6: Temperatures and workplace accidents by industry

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	A	BDE	C	F	GHI	J	K	L	MN	OPQ	RSTU
< 0°C	0.015	0.120***	0.053***	0.023**	0.089***	0.170***	0.085***	0.107***	0.073***	0.073***	0.041***
	(0.024)	(0.025)	(0.008)	(0.009)	(0.008)	(0.038)	(0.021)	(0.038)	(0.013)	(0.009)	(0.015)
0°C - 5°C	−0.044***	0.019	0.006	−0.006	0.025***	0.057*	0.000	−0.039	0.008	0.014**	−0.005
	(0.017)	(0.016)	(0.005)	(0.006)	(0.006)	(0.030)	(0.017)	(0.030)	(0.007)	(0.007)	(0.011)
5°C - 10°C	−0.024*	−0.001	0.002	−0.007	−0.001	0.028	0.011	−0.034	−0.010*	0.000	−0.013
	(0.013)	(0.014)	(0.004)	(0.005)	(0.004)	(0.021)	(0.015)	(0.023)	(0.006)	(0.005)	(0.008)
15°C - 20°C	0.008	0.012	0.022***	0.021***	0.018***	0.029	0.036**	0.035	0.023***	0.026***	0.007
	(0.012)	(0.014)	(0.004)	(0.005)	(0.004)	(0.023)	(0.015)	(0.021)	(0.006)	(0.006)	(0.009)
20°C - 25°C	0.029*	0.028	0.034***	0.048***	0.042***	0.021	0.043**	0.063**	0.058***	0.054***	0.027**
	(0.016)	(0.019)	(0.006)	(0.006)	(0.006)	(0.032)	(0.018)	(0.026)	(0.008)	(0.007)	(0.011)
25°C - 30°C	0.049**	0.041*	0.060***	0.081***	0.068***	0.002	0.081***	0.082**	0.085***	0.084***	0.055***
	(0.021)	(0.022)	(0.008)	(0.007)	(0.007)	(0.039)	(0.023)	(0.035)	(0.009)	(0.008)	(0.014)
≥ 30°C	0.083**	0.064*	0.058***	0.088***	0.075***	−0.003	0.070	0.011	0.084***	0.077***	0.054**
	(0.033)	(0.034)	(0.012)	(0.011)	(0.010)	(0.065)	(0.044)	(0.053)	(0.014)	(0.012)	(0.021)
Num.Obs.	727.578	727.578	727.578	727.578	727.578	727.578	727.578	727.578	727.578	727.578	727.578
Pseudo R2	0.135	0.190	0.390	0.462	0.486	0.352	0.383	0.231	0.501	0.501	0.291
Zipcode2 x Week FE	X	X	X	X	X	X	X	X	X	X	X
Zipcode1 x Year x Month FE	X	X	X	X	X	X	X	X	X	X	X
Day of Week FE	X	X	X	X	X	X	X	X	X	X	X
Holiday FE	X	X	X	X	X	X	X	X	X	X	X

Notes: The dependent variable is the count of daily workplace accidents. The sample period is 1996 to 2019. Standard errors in parentheses are clustered at the region-year level. A: Agriculture, forestry, and fishing; BDE: Mining, quarrying, and other industry ; C: Manufacturing; F: Construction; GHI: Wholesale, transportation, and accommodation; J: Communication; K: Financial activities; L: Real estate activities; MN: Professional, scientific, technical, administrative and support service; OPQ: Public administration, education, and healthcare; RSTU: Other services. *p<0.1; **p<0.05; ***p<0.01.

Table C.7: Most frequent causes of accidents

% Slipping, slipping off (of persons)	0.22
% Being hit, buried	0.21
% To be stung, cut, scratched	0.16
% Bump against something, strike, touch	0.08
% Slipping, falling over (of object)	0.07
% To be pinched, squeezed, caught between something	0.06
% Overburden oneself (sudden or continuous action)	0.05
% Other	0.15

Notes: The table shows the most frequent causes of accident in the accident report. "Other" summarizes 11 other causes mentioned in the accident report.

Table C.8: Temperature and health outcomes - telephone survey

	(1)	(2)	(3)	(4)
	Last 30 days		Last 7 days	
	Insomnia	Loss of Energy	Insomnia	Loss of Energy
< 0°C	−0.001	0.000	−0.001	0.001
	(0.001)	(0.002)	(0.003)	(0.003)
0°C - 5°C	0.000	0.000	−0.001	−0.002
	(0.001)	(0.001)	(0.002)	(0.002)
5°C - 10°C	0.000	0.000	0.000	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
15°C - 20°C	0.000	−0.001	0.003	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
20°C - 25°C	0.002**	−0.001	0.005***	0.002
	(0.001)	(0.001)	(0.002)	(0.002)
25°C - 30°C	0.002	−0.002	0.007***	0.002
	(0.001)	(0.001)	(0.002)	(0.002)
≥ 30°C	0.003	−0.001	0.005	0.006
	(0.002)	(0.002)	(0.004)	(0.004)
Num.Obs.	88 006	88 002	88 006	88 002
R2 Adj.	0.032	0.036	0.033	0.036
Canton x Month FE	X	X	X	X
Year x Month FE	X	X	X	X
Day of Week FE	X	X	X	X
Holiday FE	X	X	X	X

Notes: The sample period is 1992 to 2017. Standard errors in parentheses are clustered at the canton-year level. *p<0.1; **p<0.05; ***p<0.01.

Table C.9: Temperature and labor supply - robustness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All			High risk			Low risk		
< 0°C	0.009	−0.001	−0.003	−0.094	−0.127**	−0.125**	0.038	0.025	0.023
	(0.033)	(0.035)	(0.035)	(0.058)	(0.063)	(0.063)	(0.037)	(0.039)	(0.039)
0°C - 5°C	−0.001	−0.012	−0.011	−0.056	−0.047	−0.039	0.013	−0.006	−0.006
	(0.023)	(0.024)	(0.024)	(0.041)	(0.042)	(0.043)	(0.025)	(0.026)	(0.027)
5°C - 10°C	−0.017	−0.020	−0.019	−0.046	−0.073*	−0.072*	−0.007	−0.006	−0.005
	(0.024)	(0.025)	(0.025)	(0.040)	(0.042)	(0.042)	(0.026)	(0.028)	(0.028)
15°C - 20°C	0.013	−0.001	−0.002	0.009	0.019	0.015	0.018	0.000	−0.001
	(0.025)	(0.027)	(0.027)	(0.046)	(0.050)	(0.050)	(0.028)	(0.030)	(0.030)
20°C - 25°C	−0.012	−0.028	−0.032	−0.089	−0.112*	−0.113*	0.009	−0.007	−0.012
	(0.032)	(0.035)	(0.035)	(0.058)	(0.065)	(0.066)	(0.036)	(0.040)	(0.040)
25°C - 30°C	−0.043	−0.081*	−0.085*	−0.092	−0.121	−0.115	−0.024	−0.061	−0.068
	(0.040)	(0.044)	(0.045)	(0.081)	(0.094)	(0.097)	(0.043)	(0.047)	(0.047)
≥ 30°C	−0.154**	−0.194***	−0.191***	−0.275**	−0.310**	−0.296**	−0.120*	−0.167**	−0.168**
	(0.064)	(0.071)	(0.072)	(0.122)	(0.139)	(0.137)	(0.068)	(0.075)	(0.077)
Num.Obs.	418 039	418 039	418 039	84 277	84 277	84 277	333 762	333 762	333 762
R2 Adj.	0.406	0.406	0.406	0.343	0.345	0.343	0.409	0.409	0.409
Canton x Year x Month FE		X	X		X	X		X	X
District x Month FE			X			X			X
Year x Month FE	X			X			X		
District FE	X	X		X	X		X	X	
Day of Week FE	X	X	X	X	X	X	X	X	X
Holiday FE	X	X	X	X	X	X	X	X	X

Notes: The dependent variable is the number of hours worked last week. The sample period is 2010 to 2019. Standard errors in parentheses are clustered at the canton-year level. *p<0.1; **p<0.05; ***p<0.01.

Table C.10: Average daily number of workplace accidents by temperature bin

	Average number of accidents per day per year
< 0°C	618
0°C - 5°C	636
5°C - 10°C	652
10°C - 15°C	676
15°C - 20°C	703
20°C - 25°C	743
25°C - 30°C	785
≥ 30°C	806

Notes: The table shows the average number of daily accidents in the respective temperature bin per year.

Table C.11: Back-of-the-envelope calculation

	Estimate	Number of days per year in respective temperature bins	Number of accidents per day in omitted bin	Number of additional temperature-induced accidents	VSI	Additional costs
< 0°C	0.063	18.9	676	805	CHF 35,000	CHF 28 million
25°C - 30°C	0.072	31.1	676	1,515	CHF 35,000	CHF 53 million
≥ 30°C	0.074	6.01	676	302	CHF 35,000	CHF 10 million

Notes: The table summarizes the numbers used for the back-of-the-envelope calculation.

Table C.12: Climate Change projection, Back-of-the-envelope calculation

		Estimate	Future additional number of days per year in respective temperature bins	Number of accidents per day in omitted bin	Future number of additional temperature-induced accidents	VSI	Future additional costs
RCP 2.6	< 0°C	0.063	-4.7	676	-202	CHF 35,000	-CHF 7,1 million
	25°C - 30°C	0.072	+7.6	676	+371	CHF 35,000	+CHF 13 million
	≥ 30°C	0.074	+2.4	676	+119	CHF 35,000	+CHF 4 million
RCP 4.5	< 0°C	0.063	-11.2	676	-479	CHF 35,000	-CHF 17 million
	25°C - 30°C	0.072	+7.6	676	+725	CHF 35,000	+CHF 25 million
	≥ 30°C	0.074	+8.6	676	+434	CHF 35,000	+CHF 15 million
RCP 8. 5	< 0°C	0.063	-15.3	676	-653	CHF 35,000	-CHF 23 million
	25°C - 30°C	0.072	+25.4	676	+1,236	CHF 35,000	+CHF 43 million
	≥ 30°C	0.074	+29.2	676	+1,469	CHF 35,000	+CHF 51 million

Notes: The table summarizes the numbers used for the back-of-the-envelope calculation.