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ISTITUTO NAZIONALE PER L'ANALISI DELLE POLITICHE PUBBLICHE

WORKING PAPER

INAPP WP n. 119

Employment effects of temperature shocks in Italy and the role of occupational heat stress

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ISSN 2784-8701

MARZO 2024

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MARZO 2024

Il working paper è stato realizzato nell'ambito del PTA Inapp 2022-2024, con riferimento alle linee di attività afferenti alla Struttura Imprese e lavoro.

CONTENTS:

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ABSTRACT

Employment effects of temperature shocks in Italy and the role of occupational heat stress

We assess the employment impact of temperature shocks in Italy by taking into consideration the role of occupational heat stress. Combining labor-market survey data with ground-station gridded weather information, we run non-linear panel fixed-effects regression models over 2011-2019 and estimate around half percentage-point contraction in provinces' employment rates for a two Celsius degrees shock in average quarterly temperatures. This effect doubles in magnitude for provinces in coastal and southern climatic zones. By exploiting narrowly-defined 4-digit occupation survey information, we show that our results are significantly driven by individuals previously-employed in occupations relatively more exposed to extreme temperatures. This subset of non-employed significantly accrues to the private service sector and is equally split between unemployment and inactivity. Our estimates are robust to specifications controlling for key endogenous variables.

KEYWORDS: climate change, econometric analysis, employment, working conditions
JEL CODES: C22, J21, Q51, Q52, Q54

In questo articolo valutiamo l'impatto occupazionale degli shock termici in Italia prendendo in considerazione il ruolo dello stress da calore sul posto di lavoro. Aggregando i dati delle indagini sul mercato del lavoro e le informazioni meteorologiche fornite dalla griglia delle diverse stazioni monitorata dal JRC centre, utilizziamo una regressione panel a effetti fissi con l'introduzione di non linearità per il periodo 2011-2019. I nostri risultati mostrano una riduzione di circa mezzo punto percentuale dei tassi d'occupazione medi provinciali quando le stesse province sono colpite da uno shock termico trimestrale di due gradi Celsius in più. Questo effetto raddoppia per le province costiere e le zone climatiche meridionali. Sfruttando poi l'informazione sulle categorie professionali a quattro cifre, evidenziamo come i risultati siano significativamente sostenuti da individui precedentemente impiegati in occupazioni relativamente più esposte a temperature estreme. Questo sottoinsieme di non occupati proviene in misura significativa dal settore dei servizi privati e risulta equamente suddiviso tra disoccupazione e inattività. Le stime ottenute risultano altresì robuste a specificazioni che includono importanti variabili endogene.

PAROLE CHIAVE: *cambiamento climatico, analisi econometrica, occupazione, condizioni di lavoro*

CODICI JEL: C22, J21, Q51, Q52, Q54

DOI: 10.53223/InappWP_2024-119

Cite as:
Biagetti M., Intraligi V. (2024), *Employment effects of temperature shocks in Italy and the role of occupational heat stress*, Inapp Working Paper n.119, Roma, Inapp

1. Introduction

In the last decades, a fast-growing body of empirical evidence on the socio-economic impact of random weather phenomena both at the global and the country-level emerged (see Dell *et al.* 2014; Kolstad and Moore 2020). Most analyses in this field estimate larger magnitudes in developing economies (Burke *et al.* 2015, 2018; Letta and Tol 2019; Acevedo *et al.* 2020; Somanathan *et al.* 2021; Brookes Gray *et al.* 2023) since – due to the combination of low adaptation to climatic change and large agricultural employment shares – extreme weather phenomena in these countries may substantially affect aggregate production and have appreciable consequences for employment (Hsiang 2010; Dell *et al.* 2012; Kolstad and Moore 2020). Moreover, growing attention has been paid to the role increasing temperature and its relationship with health, productivity and employment-related consequences of occupational heat stress (OHS – Lundgren *et al.* 2013; Kjellstrom *et al.* 2013; Zivin and Neidell 2014; Orlov *et al.* 2019; – see Borg *et al.* 2021 and De Sario *et al.* 2023; for recent reviews of the literature). At the same time, heat-waves in the US and Europe in recent years have highlighted the need to quantify the possible macroeconomic consequences of OHS also for what concerns high-income countries (Orlov *et al.* 2019). As recently forecasted in the regional analysis by Szewczyk *et al.* (2021) indeed, productivity losses related to OHS in Europe may reach up to 1.6 per cent in 2080 – with Mediterranean countries such as Italy and Greece facing around 8 per cent losses in the worst scenario. These and other similar projections (Knittel *et al.* 2020) somehow suggest that – in order to assess the employment impact of temperature shocks and the role of OHS in advanced economies (mainly relying on the service sector rather than on manufacturing and/or agriculture, as developing ones) narrowing down the focus on Mediterranean Europe by means of country-level analysis might represent a particularly suitable strategy.

Among Mediterranean developed economies, Italy surely represents an ideal choice for empirical investigation – as it is characterized by a considerably large variety in geographical, climatic and socio-economic conditions (Cubasch *et al.* 1996; Olper *et al.* 2021). Moreover – besides documenting large climatic heterogeneity in Italian provinces – panel data econometrics elaborated in the methodological paper by Olper *et al.* (2021) clearly illustrates the advantages of modeling the effects of weather realizations on the economy by exploiting within-country local variations – especially when compared to global-level studies. However, these authors – though focusing on important economic outcomes such as province-level GDP and agricultural productivity – do not assess the impact of temperature shocks in Italy in terms of employment. We try to fill this gap by considering the impact of temperatures on province-level employment rates in Italy and the role played by occupational heat stress.

More specifically, this paper contributes to the existing literature in two main aspects. First, we assess whether – in a large developed economy such as Italy – it is possible to recover a significant impact of temperatures shocks on local employment rates. Second, to the best of our knowledge, we are the first to relate local-level employment evidence from modern panel data econometrics to OHS by means of an occupational-level measure of extreme-temperatures exposition. We do this by elaborating a narrowly-defined occupational measure of workers' exposure to extreme temperatures, and match this information with employment data to assess the role played by this important channel in the temperature-employment relationship[1].

Our results document three main empirical facts.

First, temperatures shocks in Italy as identified by modern panel data econometrics do exert a robust statistically significant negative impact on local employment rates, and this effect doubles in southern and coastal provinces compared to northern and mountainous ones.

Second, the estimated effect is significantly driven by unemployed and inactive individuals who declare to have been formerly employed – whereas in the case of non-employed individuals without previous work experience the estimate is not statistically different from zero.

Third, individuals in the first group entirely accrue to jobs highly exposed to extreme temperatures. In other words, we find that the estimated contraction in provinces' employment rate sharply reflects employment losses in jobs more exposed to OHS – while no effect is detectable in the case of all other jobs[2]. We interpret this result as strong evidence in favor of the major role played by OHS in accounting for the relationship detected. Moreover, further coefficient decomposition reveals that this sub-set of non-employed individuals significantly accrues to the private service sector (rather than to agriculture or manufacturing, as common in developing countries) and is equally distributed between the inactive and the unemployed.

The remainder of the paper is organized as follows: section 2 briefly reviews the reference literature, while section 3 illustrates the data used in the analysis and reports relevant descriptive statistics. Section 4 describes the methodology, while section 5 reports our main empirical results. Section 5 concludes.

2. Panel data applications in weather impact assessment

Weather and climate variations have garnered increasing attention in economic research, with a notable shift toward panel studies in the past decade to address identification concerns in cross-sectional approaches. Panel studies in this field exploit the exogeneity of cross-time weather variation, allowing for causal identification (Dell *et al.* 2014; Kolstad and Moore 2020). Indeed, by employing fixed-effects to control for time-invariant differences and common differences between time periods, panel data settings enhance confidence in estimating the relationship between economic outcomes and weather variations. This methodology, allowing for the removal of common trends in weather and focusing on unexpected, temporary shocks, provides a short-run response to climate change, assuming limited adaptation opportunities (Hsiang 2016).

Studies initially focused on average weather across a year, exploring factors such as temperature and precipitation, before delving into the impacts of extreme weather events like droughts and windstorms (Dell *et al.* 2014; Carleton and Hsiang 2016).

[1] A third further aspect of innovation with respect to the literature on Italy is that we rely on quarterly data rather than on annual variations (as in the study by Olper *et al.* 2021) hence we take advantage of higher data resolution and provide accurate estimates by controlling for data seasonality.

[2] In particular, we match our data with detailed survey indicators on workers' exposure to extreme temperatures – and then distinguish between high, medium and low occupational exposure. See section 3 for further details.

In examining the effects of temperature and precipitation on per-capita income, Dell, Jones, and Olken (2012) found that a 1°C increase in temperature reduces per-capita income by 1.4%, primarily in poor countries. Hsiang (2010) echoed similar findings in the Caribbean-basin countries, with a 2.5 percent decline in national output per 1°C warming, particularly impactful during the hottest season. From a comparative perspective, Acevedo *et al.* (2020) find that the negative effect of temperature on output in countries with hot climates runs through reduced investment, depressed labor productivity, poorer human health, and lower agricultural and industrial output. These authors find that – seven years after a 1 degree increase in average annual temperature – in a median low-income country aggregate output is about 2 percent lower, while the contraction in investment amounts to about 10 percent. Further, they show that hot regions in high-income countries on average suffer minor economic damages from increasing temperatures compared to hot regions in low-income countries.

A distinctive approach by Barrios, Bertinelli, and Strobl (2010) focused on Sub-Saharan Africa, utilizing weather anomalies to explain economic growth differences in the region. Their study, considering changes from country means normalized by country standard deviations, asserted that worsening rainfall conditions contributed significantly to the per-capita income gap between Sub-Saharan Africa and the rest of the developing world by the year 2000.

Beyond income effects, weather variation has been employed as instruments for national income in studies exploring outcomes such as conflict and political change. Miguel, Satyanath, and Sergenti (2004) associated civil conflict in African countries with positive temperature shocks, while Burke and Leigh (2010) linked temperature strongly to income growth, and precipitation weakly, in explaining democratization across a large sample of countries over a considerable period.

However, the short-run effects retrieved through the use of such settings may lead to biased estimates in cases of substantial adaptation potential, as it overlooks longer-term changes people can make to improve outcomes under a permanent change in climate (Hsiang 2016).

In expanding the scope of panel studies, recent research by Olper *et al*. (2021) addresses the scarcity of country-level analyses, particularly in the context of Italy. By exploiting a panel of 110 provinces observed between 1980 and 2014, the study investigates the impact of weather variables on GDP per capita and agricultural productivity. Notably, the analysis explores both linear and non-linear relationships, considering the growth rates and levels of economic outcomes under the influence of weather variables. The findings reveal considerable model uncertainty, highlighting the need for robust econometric specifications. Projections for the impact of climate change by the end of the century indicate potential losses in agriculture due to a persistent increase in average temperatures under different scenarios.

In a parallel investigation, Brookes Gray *et al*. (2023) focuses on the labor market outcomes of working-age individuals in South Africa between 2008 and 2017, assessing the impact of drought and high temperatures. Merging high-resolution weather data with detailed individual-level survey data on labor market outcomes, the study employs a fixed-effects framework to estimate causal impacts. The findings indicate that increases in the occurrence of drought reduce overall employment, with effects concentrated in the tertiary sector, amongst informal workers, and in provinces with a higher reliance on tourism.

3. Data and descriptive statistics

Our dataset combines three different data sources. To measure province-level labor market outcomes, such as the official employment rate and measures of unemployment and inactivity, we make use of the Italian National Statistical Institute (Istat) Labor Force Survey (LFS) – i.e. the *Rilevazione Continua delle Forze di Lavoro* (RCFL). RCFL data are collected quarterly and provide a very rich and detailed set of individual labor-market information such as employment status, occupational classification, sector of economic activity and geographic location (at the NUTS 3 level – i.e. Italian provinces). Importantly, RCFL also provides individual frequency weights allowing us to reconstruct the whole Italian population in each quarter we observe. For what concerns province-level employment rates, we simply compute the employed individuals' share of working-age population (age 15 to 67) by province (when different form the province of residence, we use information on the province in which the individual declares to work more often). The same applies to both our measure of province unemployment and the province-level inactivity rate. Hence, by construction, the three different measures sum up to 1 in each quarter for each province (note that we drop employment in in armed forces occupations). Summary statistics on our measures of province employment rates in 2011 and 2019 are reported in tables 1 and 2, while figure 1 plots the geographical distribution of the corresponding average values over 2011-2019. As reported in table 1, the mean provincial employment rate was 58.3% in 2011 while the unemployed individuals' share of working-age population hovered around 4.9%. The local mean province-level inactivity rate stood at 36.8%. If standard deviations are taken into account, the coefficient of variation (given by the ratio between the standard deviation and the mean) clearly shows a higher variability of the unemployed individuals' share of working-age population across Italian provinces, followed by the inactivity and the employment rates (see table 1).

Table 1. Working age population by employment status. 107x4=428 (percentage values) (2011)

Variable	Mean (1)	St. Dev. (2)	Coef. of Var. (3)=(1)/(2)	Min (4)	Max (5)
Employed	58.34	10.36	0.18	30.42	72.89
Unemployed	4.89	1.86	0.38	0.33	12.00
Inactive	36.77	9.11	0.25	23.66	61.48

Note: variables are expressed as a ratio over working age population.
Source: Authors' calculations on Italian LFS data

Eight years later, in 2019, the mean provincial employment rate had reached 60.7%, the mean unemployed individuals' share of working-age population was also higher at 6.1%, while the mean inactivity rate was lower at 33.2%. These data confirm the increase in the overall Italian labor force count occurred in the past decade. Again, the most variable ratio across provinces was that of unemployment, followed by the inactivity and the employment rate (see table 2). Increasing variability is particularly visible in the case of unemployment (from 0.38 to 0.49, i.e. 23 p.p. increase). This evidence hints at worrisome unemployment spells that we know were continuously hitting some (southern) provinces, which points at the dual nature of the Italian labor market.

Table 2. Working age population by employment status. 107x4=428 (percentage values) (2019)

Variable	Mean (1)	St. Dev. (2)	Coef. of Var. (3)=(1)/(2)	Min (4)	Max (5)
Employed	60.72	10.99	0.18	32.10	75.58
Unemployed	6.11	2.86	0.49	1.57	16.47
Inactive	33.18	8.76	0.26	21.69	55.86

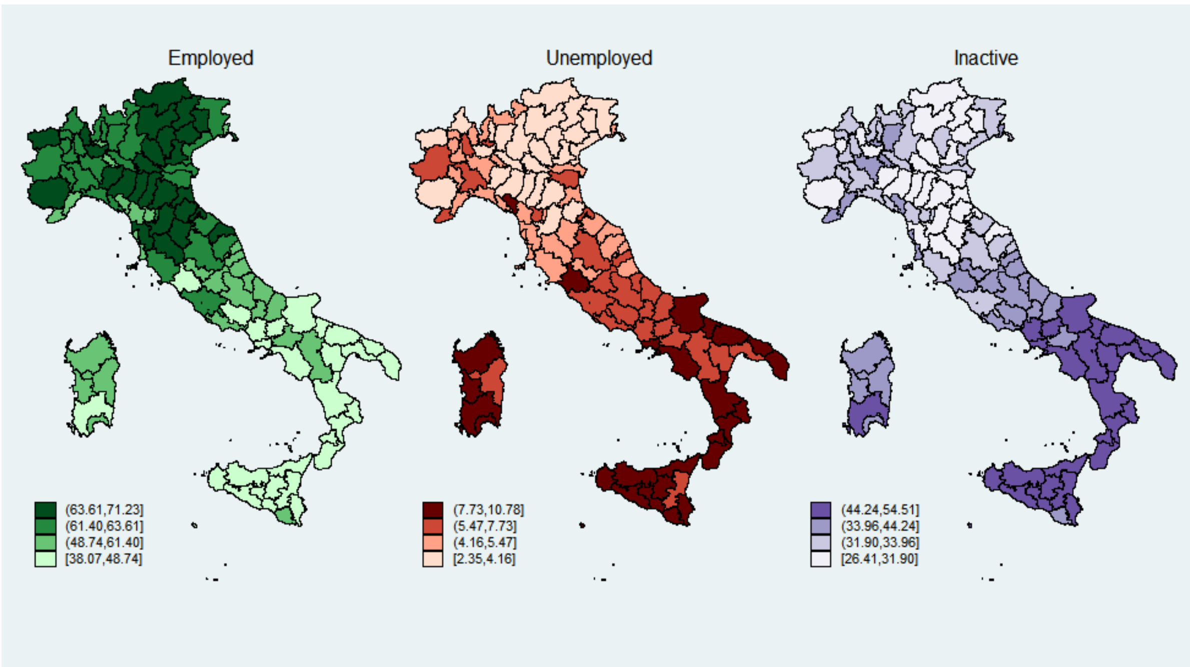
Note: variables are expressed as a ratio over working age population.
Source: Authors' calculations on Italian LFS data

Figure 1 clearly exhibits the well-known stylized facts in the Italian labor market: the highest employment rates can be found in the provinces of Tuscany, Emilia-Romagna, Veneto, Lombardy and some northern and less populated provinces (Aosta, Trento, Bolzano) along with the provinces of Cuneo (close to Turin), Pordenone (just east of Treviso) and Ancona (in the Marche region). Unsurprisingly, the lowest employment rates are found in Southern provinces and, among central provinces, in two out of five provinces of Latium (Frosinone and Viterbo).

Conversely, the unemployed individuals' share of working-age populations is systematically higher in the Southern part of the Italian Peninsula (the entire regions of Sicily, Calabria, Apulia, and the southern, coastal and more populated part of Campania) alongside Sardinian provinces, Viterbo and, interestingly, in the smaller province of Lucca (Northern Tuscany, close to the southern boundaries of Liguria).

Lastly, inactivity rates clearly posit a spatial path very similar to that of unemployment, confirming a usual outcome in labor economics, i.e. not all unemployment ends with job seekers finding a job, while many spells of unemployment end when the unemployed leave the labor force.

Figure 1. Individuals' share of working-age population by occupational status and province (average 2011-2019)



Source: Authors' calculations on IT-LFS (RCFL-Istat) data

The second data source is the Inapp-Istat *Indagine Campionaria sulle Professioni* 2013 (ICP 2013), concerning detailed occupational information about skill-requirements, job tasks, and several other job-characteristics in Italy. In particular, to identify those occupational groups that are relatively more exposed to extreme temperatures, we make use of question H.23 (in the working conditions section), where respondents are asked to answer the following question: i) *in doing our job, how often are you exposed to very high temperatures (above 32 °C) or very low ones (below 0 °C)?* Answers are expressed on a 1 to 5 scale, where 1 equals to *never* and 5 means *every day*. By construction, ICP survey results are provided by Inapp-Istat in the format of a standardized index rescaled on a 0–100 range, according to the following formula:

$$X = \left(\frac{Y - min}{max - min}\right) * 100 \tag{1}$$

where Y is the answer (from 1 to 5) to the question and *max* and *min* are the maximum and the minimum values reported by respondents within each 5-digit occupation classified according to the *Classificazione delle Professioni* 2011 (CP2011). To allow this information to match into RCFL data, we average this index at the 4-digit level, and then identify as *heat-stress exposed* jobs (hereafter, *HSE* jobs) those occupations falling within the employment-weighted top-tertile (top-third) of such measure in 2011 – i.e. about 7.255 million workers according to RCFL frequency weights. We consider these jobs as subject to high exposure to OHS. This means that all remaining jobs represent, by construction, the lower 2/3 of employment in terms of exposition to extreme temperatures in the base year – i.e. about 14.5 million workers – that we may consider as subject to low or medium exposure to OHS. Hereafter, we refer to these jobs as *non-heat-stress exposed* jobs (*non-HSE jobs*). We summarize relevant information about our measure in table 3, describing the distribution of occupations identified as *HSE-jobs* (4-digit) across broad occupational sub-major groups (i.e. 2-digit).

Note that the group of occupations selected by using this procedure identifies groups of jobs exposed to extreme temperatures for different reasons – either because mainly performing outdoor job-tasks (in Italy, plausibly most frequently exposed to high temperatures – as ships' deck crews and related workers, fishers and hunters, gardeners, building construction workers ecc.) either because of high proximity to heat sources (e.g. firers and stone-cutters, metal/glass blast-furnace operators, cooks ecc.).

As for weather variables, we make use of European Commission Joint Research Centre (JRC) AGRI4CAST data, reporting ground-station gridded daily weather information covering 650 different Italian geographic points from year 1979 onward[3]. These data include: a) precipitations (mm/day); b) radiations (KJ/m2/day); c) vapor pressure (hPa), windspeed (mean daily wind speed at 10 m measured in m/s), potential evapotranspiration (mm/day). We collapse daily municipality-level information to quarterly data in 105 different Italian provinces for a total of 36 time-points over the period 2011-2019. Since we are interested in the effect of weather-shocks for different occupational groups, we decided to set year 2011 as the starting point of our analysis, in the effort of avoiding possible consistency issues arising from the break between the CP2001 and the CP2011 Italian occupational classification.

[3] We matched gridded AGRI4CAST data with Italian municipalities by using the website https://bitly.ws/3fwAQ.

Table 3. Distribution of HSE jobs by occupational 2-digit sub-major groups (CP2011)

CP2011 2-digit code	Nomenclature	Number of 4-digit jobs	Number of HSE jobs	HSE jobs incidence in two-digit code	HSE Jobs employment share in 2011
11	Managers, Senior Officials and Legislators	14	0	0.00	0.00
12	Administrative and Large Firm Managers	26	2	7.69	0.03
13	Small Firm Managers	9	2	22.22	0.44
21	Mathematical Science and Related Professionals	6	0	0.00	0.00
22	Engineering and Related Professionals	10	3	30.00	0.37
23	Life-science Professionals	5	1	20.00	0.05
24	Health Professionals	8	0	0.00	0.00
25	Social Science and Related Professionals	25	1	4.00	0.01
26	Teaching Professionals	24	0	0.00	0.00
31	Science, Engineering and Business and Administration Associate Professionals	34	16	47.06	1.71
32	Life and Health Science Associate Professionals	10	2	20.00	0.08
33	Business and Administration and Related Professionals	24	3	12.50	0.60
34	Public and Personal Services Associate Professionals	30	6	20.00	0.34
41	General and Keyboard Clerks	7	0	0.00	0.00
42	Customer Services Clerks	10	0	0.00	0.00
43	Administrative and Financial Clerks	8	1	12.50	1.12
44	Material Recording Clerks	5	2	40.00	0.33
51	Sales Workers	13	2	15.38	0.23
52	Restaurant and Accommodation Services Workers	8	4	50.00	2.21
53	Health and Social Care Workers	1	0	0.00	0.00
54	Personal, Cultural and Protective Services Workers	24	11	45.83	1.53
61	Building and Related Trades Workers (excluding Electricians)	22	22	100.00	5.99
62	Electrical and Electronic Trades Workers	25	19	76.00	4.72
63	Handicraft and Printing Workers	17	2	11.76	0.08
64	Market-oriented Skilled Agricultural, Forestry, Fishery and Hunting Workers	17	17	100.00	2.36
65	Food Processing, Woodworking, Garment and Other Craft and Related Trades Workers	20	10	50.00	1.77
71	Stationary Plant and Machine Operators	23	20	86.96	1.16
72	Assemblers	28	9	32.14	0.71
73	Agricultural and Food Processing Plant Operators	11	10	90.91	0.33
74	Drivers and Mobile Plant Operators	17	17	100.00	3.65
81	Services and Trade Elementary workers	15	7	46.67	1.29
82	Personal Services Elementary Workers	2	1	50.00	0.03
83	Agricultural, Forestry, Fishery and Hunting Elementary Workers	5	5	100.00	1.42
84	Manufacturing, Mining and Construction Elementary Workers	4	4	100.00	1.09
Total jobs		507	199	Total share	33.64

Source: our calculations on ICP Inapp-Istat and IT-LFS (RCFL-Istat) data

Table 4 and 5 summarize these data in year 2011 and 2019, respectively, while figure 2 plots the corresponding geographical distribution by averaging quarterly data over the whole time-span 2011-2019.

In 2011, mean provincial temperatures reached 14.66 degrees Celsius, there were 1.63 average millimeters of rain per day: windspeed was about 2.58 meters per second at a height of 10 meters above sea level. Interestingly, these phenomena show a high variability across provinces. This variability ranges from 0.36 in the case of wind speed to 0.55 in the case of (potential) evapotranspiration (see table 4 below).

Table 4. 105 provinces x 4 quarters = 420 data points (2011)

Variable	Mean (1)	St. Dev. (2)	Coef. of Var. (3)=(1)/(2)	Min (4)	Max (5)
Temperature	14.66	6.60	0.45	-0.59	26.05
Precipitation	1.63	0.73	0.45	0.21	4.54
Radiation	15120.84	6659.81	0.44	6128.98	24875.07
Vapor pressure	12.50	4.40	0.35	3.87	22.52
Wind speed	2.58	0.92	0.36	0.90	5.28
Evapotranspiration	2.86	1.56	0.55	0.75	6.14

Note: units of measure: temperature degrees Celsius °, precipitations: millimeters per day, total global radiations KJ per square meter per day; vapor pressure hPa (Hectopascal equivalent to a force of a 100 Newton on a one square meter surface), daily mean windspeed at a height of 10 meters, meter per second; potential evapotranspiration from a crop canopy, millimeters per day.
Source: Authors' calculation on JRC data

In 2019, mean provincial temperatures had reached 15 degrees Celsius (+.34 degrees, i.e. +2% in eight years), mean precipitations totaled 2.6 millimeters per day, windspeed 2.80 meter per second. Of the six weather/climate phenomena measured, only radiations recorded a very mild and almost insignificant change (-88 KJ per square meter a day, i.e. -1%). Interestingly, only variability in precipitation increased, suggesting rainfalls can be considered the only localized weather phenomenon we have collected data for (see table 5 below).

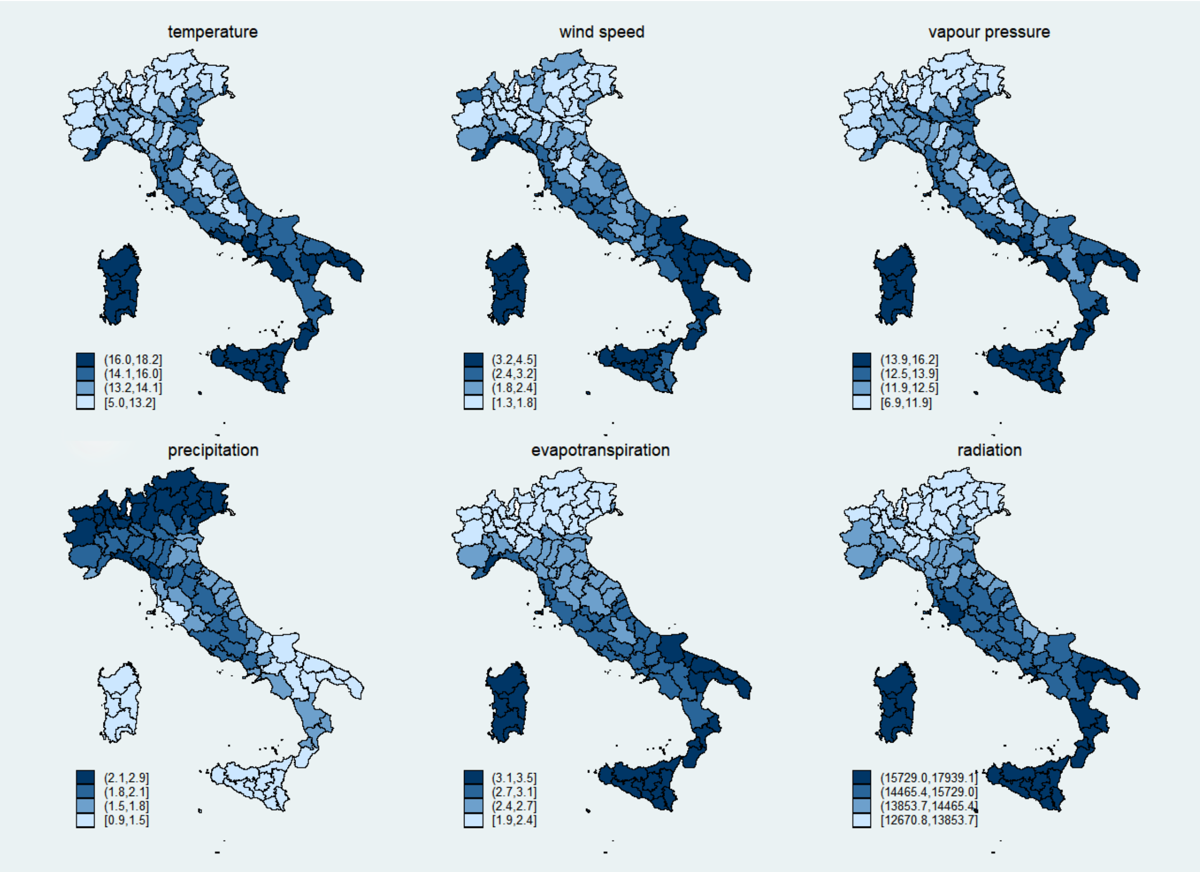
Table 5. 105 provinces x4 quarters = 420 data points (2019)

Variable	Mean (1)	St. Dev. (2)	Coef. of Var. (3)=(1)/(2)	Min (4)	Max (5)
Temperature	15.00	6.32	0.42	-1.07	26.52
Precipitation	2.60	2.24	0.86	0.36	14.95
Radiation	15031.73	6175.72	0.41	5238.35	24918.31
Vapor pressure	13.00	4.84	0.37	3.10	25.26
Wind speed	2.80	0.88	0.31	1.22	5.53
Evapotranspiration	2.89	1.45	0.50	0.66	5.86

Note: units of measure: temperature degrees Celsius °, precipitations: millimeters per day, total global radiations KJ per square meter per day; vapor pressure hPa (Hectopascal equivalent to a force of a 100 Newton on a one square meter surface), daily mean windspeed at a height of 10 meters, meter per second; potential evapotranspiration from a crop canopy, millimeters per day.
Source: Authors' calculation on JRC data

Figure 2 shows that on average, temperatures are obviously higher in the Southern part of the Italian peninsula, similarly to vapor pressure, wind speed (with the notable exception of Ligurian provinces) and radiations. Conversely, precipitations are larger in the Northern side, particularly in the sub-alpine area of the country.

Figure 2. JRC AGRI4CAST variables by province (2011-2019)



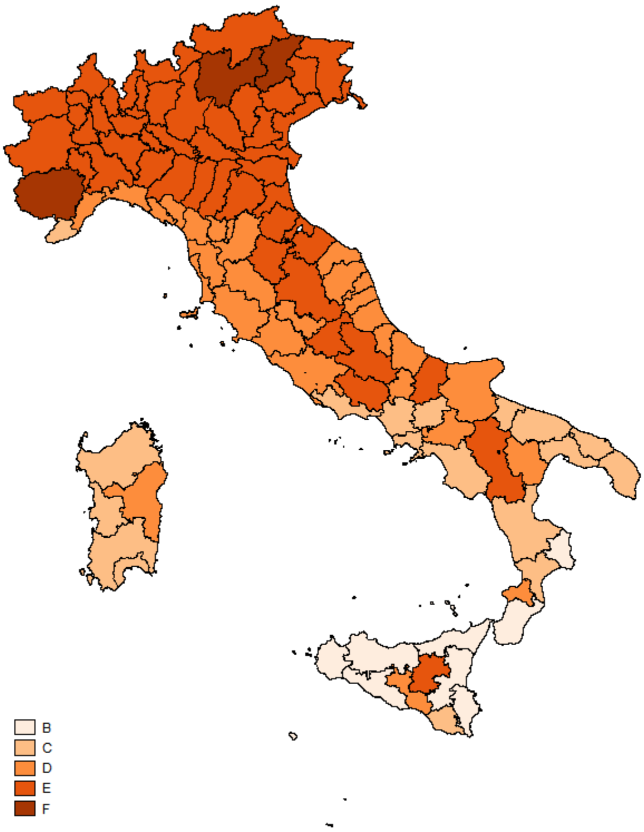
Note: quarterly values averages over 2011-2019.
Source: our elaborations on AGRI4CAST data

Last, to account for differences in Italian climatic zones, we rely on detailed information from the official Italian classification of municipality-level degree-days (DD)[4]. According to the aforementioned classification, Italy is divided into 6 climate zones defined on a degree-days basis (A, B, C, D, E, F). Figure 3 provides graphical representation of the geographical distribution[5].

[4] See Decree of the President of the Italian Republic (DPR) 412/93 https://bitly.ws/3fwMa, annex A. In particular, we assigned to each province the climatic-zone category of the corresponding capital city. For twin-headed provinces, we assigned the province to the climatic zone resulting from the population-weighted average DD of the two capitals.

[5] Only two small Italian municipalities fall in the climatic zone A (the municipality of Lampedusa and Linosa, and Porto Empedocle) both in the Agrigento province, and therefore were assigned to the Agrigento municipality climate zone, B.

Figure 3. Italian Provinces by climatic zone



Note: climatic zones are classified by degree days (DD) intervals (B: 601-900, C: - 901-1400, D: 1401-2100, E: 2101-3000. F:>3001).
Source: Our elaborations on data from the Decree of the President of the Republic (DPR) 412/93 and subsequent amendments and additions

4. Estimation strategy

In order to estimate the effect of temperature shocks on Italian employment rates at the local-level, we exploit variations over time within provinces by employing a standard fixed-effects panel method. Following Dell *et al.* (2014), our base specification takes the following form:

$$y_{irqt} = \alpha + \beta T_{irqt} + \gamma C_{irqt} + \nu T_{irqt} * T_{irq,1979} + \mu_i + q_q + \theta_{rt} + \tau_{qt} + \varepsilon_{irqt} \; ; \qquad (2)$$

where y_{irqt} is individuals' share of working-age population by employment status in province *i* climatic zone *r* quarter *q* in year *t*, T_{irqt} are province-level quarterly-averaged daily temperatures, μ_i are province fixed-effects, q_q represent quarter-dummies and τ_{qt} is a smooth linear time-trend common to all provinces. All other weather variables from AGRI4CAST are included in vector C. These are, namely, precipitations, wind speed, solar radiation, vapor pressure and potential evapotranspiration (see section 2). Following Deschênes and Greenstone (2007), we do account for non-linear effects in temperature by also including the interaction term $T_{irqt} * T_{irq,1979}$ – where $T_{irq,1979}$ is province *i* climatic zone *r* quarter *q* temperature in 1979 – i.e. the first year observable in AGRI4CAST data. Coefficient ν, whether significant, may indicate either adaptation or intensification effects. Wherever adaptation to weather shocks is not substantial, then the short-run effect might be even used to infer the long-run effect – since this would imply that economic agents are less prone to alter their economic behavior in response to weather shocks (Kolstad and Moore 2020). Additionally, we account for the existence of different climatic zones, rather than administrative or economic geographical entities, allowing us to account for heterogeneities in the effects of temperature – and this may be particularly true in the case of climatically heterogeneous countries such as Italy[6]. As illustrated in equation (2), we do this by controlling for climatic-zones specific year time trends as indicated by the term θ_{rt}. This yearly time fixed-effect enters by climatic-zone subgroups (*r*) to allow for differential trends in the different climatic regions of Italian peninsula (see section 2). This means that provinces' common trends in weather (climate change) are modeled both as on aggregate (τ_{qt}) and as climatic-zone specific, and that the variation used for estimation tends to come from temporary and unexpected shocks in weather (see Kolstad and Moore 2020; Schlenker 2010). Finally, ε_{iqt} represent error terms that are assumed to be independent and identically distributed[7].

In order to carry out an unbiased short-run estimation of weather effects on economic outcomes (as employment rates) in our benchmark model we do not introduce non-weather/non-climatic controls. In a nutshell, the argument is that economic/non-weather control variables might be themselves modeled as response variables for weather realizations, and this would result in the well-known "over-controlling problem" (see Dell *et al.* 2014, 744). Indeed, this would hinder achieving unbiased estimates not only in a cross-sectional framework but also in fixed-effects panel data settings – because of the correlation of unobservable omitted variables with both the economic/demographic controls and the response variable. Thus, the piece of advice is to not encumber too much the control vector by including possibly endogenous economic controls. Differently, the best practice adopted in this literature is to include additional exogenous weather variables, and to consider potentially endogenous economic controls only in presence of strong theoretical arguments (such controls should not be correlated with unobservables that are correlated with both the explanatory and the response variable)[8]. Nonetheless, in section 5.3 we test the robustness of our results to the inclusion of key provinces' economic and socio-demographic characteristics (provinces' industry, occupational and demographic structure) in our model, and show no substantial changes in our main results.

5. Results

5.1 National estimate and north-south heterogeneities

In this section we report the main results obtained by employing the estimation strategy described in section 4. We first begin by estimating the impact of temperature shocks on Italian provinces' employment rates by considering all climatic zones (table 6 column 1) and then split the regression

[6] Of course, there is always the possibility of local spillovers which would be better analyzed through a spatial set-up. This potential bias is however reduced by the presence of a number of weather control variables which have an effect on local outcomes.

[7] Since our response variable is related to population, we use population weights instead of area weights (i.e. provinces' share of working age population in 2011).

[8] All in all, it is worth recalling that exogeneity of weather realizations in economics is peacefully accepted, as no economic agent can directly or indirectly influence weather.

sample in, on the one hand, northern and mountainous areas (column 2) and, on the other hand, southern and coastal ones (column 3 – see section 3 for more details about Italian climatic zones). We do this to assess whether different broad climatic areas in Italy do exhibit different employment responses to temperature shocks.

As table 6 clearly points out, model described in equation (2) detects a statistically significant negative impact of temperatures on employment rates at the province level. More specifically, the estimate of –0.24 on temperature in column 1 shows that the model predicts around half percentage point contraction in the employment rate for a modest two Celius degrees shock in average quarterly temperatures. As for the regression coefficient on the interaction term – ν, accounting for possible non-linearity in the relationship estimated – the negative coefficient of around -0.01 indicates that – for each quarter – provinces with higher temperatures in 1979 suffer systematically larger contractions in the employment rate. Nevertheless, such statistically significant difference results relatively small, and might be somehow interpreted as evidence of no adaptation to temperature shocks (since it indicates modest intensification of temperature shocks effects) in Italian provinces.

To check for the existence of possible heterogeneities in different geographical areas, we split the sample in two parts. In column 2 we only consider climatic zones E and F, sizably matching northern and mountainous provinces. Though not completely comparable with estimates in column 1 (differences in sample sizes, province-weights structure and number of climatic-zone dummies) the effect estimated in column 2 reveals that no appreciable difference arises when considering colder climatic zones compared to the whole country, both in the estimate on temperatures (-0.29) and on the interaction term (-0.01).

Table 6. Temperature and employment rate by province (2011-2019 quarterly data)

	DEP VAR: EMPLOYMENT RATE BY PROVINCE		
	(1)	**(2)**	**(3)**
	Whole sample	**Northern + montainous**	**Coastal + Southern**
Temperature	-0.237***	-0.287***	-0.479***
	(0.065)	(0.108)	(0.110)
Temperature X 1979 temp.	-0.008***	-0.010***	0.002
	(0.003)	(0.004)	(0.006)
Other weather controls	yes	yes	yes
Climatic zone X year	yes	yes	yes
Quarter FE	yes	yes	yes
Province FE	yes	yes	yes
Constant	70.304	-67.655	266.901***
	(157.624)	(162.615)	(35.888)
N	3,780	1,800	1,980
R^2 (within)	0.239	0.280	0.209
Number of provinces	105	50	55

Note: N=(105 provinces × 9 years × 4 quarters)=3,780 observations. All models include a 5 weather/climate control variables other than temperature (precipitations, wind speed, solar radiation, vapor pressure, potential evapotranspiration) a linear time-trend, 5 Italian climatic zone dummies interacted with a yearly time-trend, quarterly fixed effects, the quarterly 1979 temperature and its interaction with current temperatures. Northern + mountainous stands for climatic zones E and F; coastal + southern indicates zones B, C and D. All models are weighted by provinces' share of national working-age population in 2011. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Source: Authors' calculations on Italian LFS and AGRI4CAST JRC data

Differently, in the case of provinces located in southern and coastal climatic zones (zones B, C and D - column 3) the impact of temperature shocks on employed individuals' share of working-age population is exactly as twice as that estimated in column 1 (β=-0.48). In this case the estimate on the interaction term, differently from column 2, is not statistically different from zero, suggesting no intensification or adaptation to temperature shocks in provinces geographically characterized by higher temperatures.

Comparison between columns in table 6 not only reveals that the employment impact of temperature shocks in Italy is significant and substantial, but also that geographical heterogeneities are simmering. Nevertheless, evidence from northern and mountainous provinces is considerably close to the national-level effect, suggesting that the total effect is not simply driven by typically warmer southern and coastal provinces. In what follows, we decompose the main estimate in order to provide consistent evidence on the characteristics of changes in individuals' employment status behind the interplay under investigation, in particular, those related to previous work experiences among both the unemployed and the inactive.

5.2 Non-employment and the role of OHS: aggregate and industry-level evidence

In this subsection we rely on employment data information about non-employed individuals' previous jobs in order to assess which individuals' characteristics drive the estimate obtained in section 5.1 and the role of OHS. We first begin by assessing to what extent the increase in the average number of non-employed individuals that our model detects in response to higher temperatures is related to job-loss phenomena. We do this by estimating the impact of our main explanatory variable on the non-employed individuals' share of working age population – i.e. the ones' complement of the employed individuals' share of working-age population or, in other words, of the employment rate regressed in table 7 column1 – and then by splitting the numerator of the response variable between those declaring to have been engaged in previous work experiences (column 2) and those who do not (column 3). With reference to the estimate of 0.237 in column 1, there is no surprise, as it is by-default the opposite of the estimate reported in table 6 (the same of course applies to parameter of interaction term, ν, and all other coefficients). On the contrary, for what concerns coefficients in columns 2 and 3, the evidence we obtain really stands out – underlining that the effect estimated is exclusively driven by formerly-employed individuals (0.155, significant at the 1 per cent level) while no significant evidence emerges in the case of individuals declaring to have not been engaged in previous job experience. This seems to suggest that the temperature-shock effect detected by our model is driven by a push-out phenomenon keeping workers away from employment, though at this stage of the analysis we choose to not focus on the destination of these 'flows' (unemployment and inactivity, subsection 5.3) but to first examine the role played by OHS[9]. We do this by taking advantage of the occupational-level measure described in section 3 (HSE jobs). More specifically, we split the numerator of the response variable regressed in table 7 column 2 – i.e. the number of non-employed declaring to have been formerly employed – in those who declare to held a job classified as HSE job

[9] Of course, the cross-sectional structure of IT-LFS (RCFL) data – though providing useful information on workers' previous spells – does not allow for longitudinal identification of workers' flows between different employment-status.

(column 4) and those who declare to held a non-HSE job (column 5). Evidence emerging from the comparison between coefficients in column 2, 4 and 5 is not only striking but also impressive, as it turns out that the estimated average increase in non-employed individuals with previous work experience is fully represented by workers formerly employed in HSE jobs (estimate of 0.155 vs. 0.159, respectively) while in the case of non HSE jobs the coefficient amounts to a zero sharp. We interpret this result as more than clear evidence that the local employment effects detected by our econometric set up is mirroring occupational-heat-stress related phenomena.

Moving to panel B (columns 6 to 10) we drill down our coefficient decomposition procedure by splitting the numerator of the response variable regressed in table 7 column 4 (formerly employed in HSE jobs) by broad economic activity branches. In particular, our results points put that, in the case of non-employment from HSE jobs, the effect of temperature shock are exclusively driven by the service sector (column 8) and, in particular, by private services (column 10). Hence, these results suggest that temperature-shocks propel local employment rates mainly through negative variations of employment in HSE jobs accruing to the private service sector (β=0.103, out of 0.113 estimated in the case of overall services) – as no statistically significant impact is retrieved in the case of agriculture, manufacturing and public services (columns 6, 7 and 9 respectively).

Table 7. Temperature and non-employed individuals' share of working-age population by province (2011-2019, quarterly data)

DEP VAR: NON-EMPLOYED INDIVIDUALS BY PROVINCE (SHARE OF WORKING AGE POPULATION)										
	Panel A					**Panel B**				
						FORMERLY EMPLOYED IN HSE-JOBS ONLY				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
	All	**Formerly employed**	**Non- formerly employed**	**Formerly employed in HSE jobs**	**Formerly employed in non-HSE jobs**	**Agriculture**	**Manufacturing**	**Services**	**Public services**	**Private services**
Temperature	0.237*** (0.065)	0.155*** (0.055)	0.082 (0.053)	0.159*** (0.038)	-0.004 (0.034)	0.018 (0.015)	0.029 (0.021)	0.113*** (0.027)	0.010 (0.007)	0.103*** (0.026)
Temperature X 1979 temp.	0.008*** (0.003)	0.004* (0.002)	-0.079 (0.053)	0.003** (0.002)	0.000 (0.001)	-0.001 (0.001)	0.002* (0.001)	0.003** (0.001)	0.000 (0.000)	0.002** (0.001)
Other weather controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Climatic zone X year	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Quarter FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Province FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Constant	29.696 (157.624)	243.996* (133.511)	-214.300 (127.516)	24.456 (93.039)	219.540*** (82.684)	71.573** (33.813)	39.179 (49.705)	-81.116 (64.641)	53.040*** (17.562)	-134.156** (61.962)
N	3,780	3,780	3,780	3,780	3,780	3,780	3,780	3,780	3,780	3,780
R^2 (within)	0.239	0.117	0.182	0.119	0.072	0.069	0.131	0.104	0.022	0.114
Number of provinces	105	105	105	105	105	105	105	105	105	105

Note: N=(105 provinces × 9 years × 4 quarters)=3,780 observations. All models include a 5 weather/climate control variables other than temperature (precipitations, wind speed, solar radiation, vapor pressure, potential evapotranspiration) a linear time-trend, 5 Italian climatic zone dummies interacted with a yearly time-trend, quarterly fixed effects, the quarterly 1979 temperature and its interaction with current temperatures. Northern + mountainous stands for climatic zones E and F; coastal + southern indicates zones B, C and D. All models are weighted by provinces' share of national working-age population in 2011. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.
Source: Authors' calculations on Italian LFS and AGRI4CAST JRC data

5.3 Non-employment from HSE jobs by occupational status

In this subsection, we decompose the main result obtained in the previous subsection, that is, the β of 0.159 estimated in the case of non-employed individuals declaring to have been previously employed in a HSE job. In particular, we delve into the characteristics of changes in the occupational status of this group (i.e. from employment to unemployment and from employment to inactivity) by taking into consideration the role of the service sector only. To ease comparison, table 8 column 1 reports again the coefficient we are interested in decomposing. In the case of the unemployed, estimates are reported in columns 2 through 5, while columns 6-9 are concerned with the inactive. As a direct comparison between columns 1, 2 and 6 indicates, the average increase in non-employment from HSE jobs is almost equally split between unemployment and inactivity (0.072 vs. 0.086, respectively – both significant at the 1 per cent level). Similar observations may be formulated in the case of other estimates in table 8, as the relative size of coefficients for all further decomposition remains substantially unchanged, with slightly higher coefficients in the case of the inactive (respectively, 0.053 vs. 0.061 in the case of aggregated services and 0.049 vs. 0.055 in the case of private services).

Table 8. Temperature and previously-employed in heat-stress exposed jobs by province (2011-2019, quarterly data)

DEP VAR: NON-EMPLOYED INDIVIDUALS PREVIOUSLY EMPLOYED IN HEAT-STRESS EXPOSED JOBS BY PROVINCE (SHARE OF WORKING AGE POPULATION)									
		UNEMPLOYED				INACTIVE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	**All sectors**	**Services**	**Public services**	**Private services**	**All sectors**	**Services**	**Public services**	**Private services**
Temperature	0.159***	0.072***	0.053***	0.004	0.049***	0.086***	0.061***	0.006	0.055***
	(0.038)	(0.022)	(0.015)	(0.003)	(0.014)	(0.030)	(0.021)	(0.006)	(0.020)
Temperature X 1979 temp.	0.003**	0.001	0.001	0.000**	0.000	0.002**	0.002**	0.000	0.002**
	(0.002)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
Other weather controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Climatic zone X year	yes	yes	yes	yes	yes	yes	yes	yes	yes
Quarter FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Province FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Constant	24.456	-33.763	-15.205	10.997	-26.245	57.916	-64.766	42.043***	-106.809**
	(93.039)	(54.186)	(35.015)	(7.336)	(34.159)	(71.614)	(50.923)	(15.680)	-48.233
N	3,780	3,778	3,741	3,780	3,735	3,780	3,780	3,780	3,780
R^2 (within)	0.119	0.118	0.106	0.011	0.109	0.083	0.049	0.016	0.056
Number of provinces	105	105	105	105	105	105	105	105	105

Note: N=(105 provinces × 9 years × 4 quarters)=3,780 observations. All models include a 5 weather/climate control variables other than temperature (precipitations, wind speed, solar radiation, vapor pressure, potential evapotranspiration) a linear time-trend, 5 Italian climatic zone dummies interacted with a yearly time-trend, quarterly fixed effects, the quarterly 1979 temperature and its interaction with current temperatures. Northern + mountainous stands for climatic zones E and F; coastal + southern indicates zones B, C and D. All models are weighted by provinces' share of national working-age population in 2011. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.
Source: Authors' calculations on Italian LFS and AGRI4CAST JRC data

5.4 Robustness to non-weather controls

In this last subsection, we test for the robustness of our main result (the estimate on the employment rate reported in table 6 column 1) to the inclusion of key provinces' economic and socio-demographic characteristics in the control vector (see equation 2).

Table 9. Temperature and employment rate by province (2011-2019, quarterly data)

DEP VAR: EMPLOYMENT RATE BY PROVINCE				
	(1)	**(2)**	**(3)**	**(4)**
Temperature	-0.255***	-0.248***	-0.243***	-0.278***
	(0.060)	(0.064)	(0.065)	(0.060)
Temperature X 1979 temp.	-0.006***	-0.008***	-0.008***	-0.006***
	(0.002)	(0.003)	(0.003)	(0.002)
Manufacturing share	51.718***			51.537***
	(2.064)			(2.069)
50+ share		-42.249***		-31.210***
		(4.457)		(4.147)
Professionals' share			4.112**	9.847***
			(1.762)	(1.623)
Other weather controls	yes	yes	yes	yes
Climatic zone X year	yes	yes	yes	yes
Quarter FE	yes	yes	yes	yes
Province FE	yes	yes	yes	yes
Constant	2.257	44.054	83.897	15.660
	(145.662)	(155.769)	(157.636)	(144.023)
N	3,780	3,780	3,780	3,780
R^2 (within)	0.351	0.258	0.241	0.367
Number of provinces	105	105	105	105

Note: N=(105 provinces × 9 years × 4 quarters)=3,780 observations. All models include a 5 weather/climate control variables other than temperature (precipitations, wind speed, solar radiation, vapor pressure, potential evapotranspiration) a linear time-trend, 5 Italian climatic zone dummies interacted with a yearly time-trend, quarterly fixed effects, the quarterly 1979 temperature and its interaction with current temperatures. Northern + mountainous stands for climatic zones E and F; coastal + southern indicates zones B, C and D. Where indicated, regressions include: provinces' broad manufacturing-sector employment share (including construction), the individuals aged 50+ share of working age population and the joint employment share of managers and professionals (CP2011 major groups 1 and 2, respectively) All models are weighted by provinces' share of national working-age population in 2011. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1.
Source: Authors' calculations on Italian LFS and AGRI4CAST JRC data

To begin with, we first consider the broad manufacturing employment share in table 9 column 1, which enters with the expected sign and very high statistical significance (provinces' experiencing increasing manufacturing shares plausibly experiences positive demand shocks with positive consequences for local employment). In column 2 we control for the age-structure of Italian provinces by including older adults' (50+ aged) share of the working-age population. The negative sign on this coefficient is also expected, as it straightforwardly mirrors higher proximity to retirement-age, higher propensity to sick leave and other employment consequences of ageing populations. In column 3 we are concerned instead in testing the robustness of our result to a local-level measure of workers' skills such as the employment share of managers and professionals (occupational major groups 1 and 2, respectively). Of course, the sign of this coefficient turns out to be positive, as provinces' experiencing increases in high-skilled labor are also plausibly experiencing increasing employment due to positive spillover effects (see Glaeser and Maré 2001, and related literature on the spatial concentration of skills). In the last column 4, the three aforementioned economic controls are inserted simultaneously. Their signs do not change; but what is more relevant here is that their compounded effect on the employment rate further increases the size of the coefficient (-0.278, compared to -0.237 estimated in the benchmark model in table 6). This depressing effect hints at a plausible upward bias of potentially endogenous economic regressors, thereby forcing researchers to discard them from a panel data setting as suggested by the literature (Dell *et al.* 2014).

6. Concluding remarks

In this study, we analyze the relationship between temperature shocks and employment rates at the local level in Italy, with a particular focus on the role of occupational heat stress (OHS). The main objective was to assess the impact of temperature shocks on employment rates, considering the diverse climatic and socio-economic conditions present across Italian provinces.

Crucially, our study identifies OHS as a pivotal factor in the temperature-employment relation. By leveraging narrowly-defined 4-digit occupation survey data, we unveil that the national-level impact is primarily driven by workers previously employed in occupations more exposed to extreme temperatures.

Weather conditions such as outdoor temperatures (alongside work factors, e.g. workplace-generated heat, physical exertion ecc.) may of course worsen OHS. This, in turn, entails different adverse consequences for employment. The literature on OHS (Borg *et al.* 2021) does highlight at least three important channels: firstly, individual-level psychological and psycho-behavioral responses to OHS may imply decreased work efficiency and reduced labor productivity. Secondly, OHS may encourage workplace policies limiting working time or, thirdly, even induce employee resignation. These reactions to OHS may additionally reduce labor productivity. All of these channels – exacerbated by temperature shocks – may of course have potentially dismal consequences on employment at the local level.

As temperature extremes become more frequent, understanding the implications for employment is paramount. Our results, robust to specifications controlling for key endogenous economic variables, suggest the need for targeted policy interventions, especially in sectors susceptible to OHS. Future research endeavors could explore the broader socio-economic implications of temperature shocks and further refine our understanding of the intricate relationship between climate, employment, and occupational health in advanced economies.

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INAPP
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