Climate change and test scores: the case of heatwaves in Italy

Introduction

One of the outcomes of climate change is the increased level of temperatures worldwide and the occurence of heatwaves. High temperatures affect several dimensions of human behaviour, health, and cognitive functioning (Heal & Park,2016; Randell & Gray, 2019; Randell & Gray, 2016 Cedeño et al. 2016).

Both experimental and observational studies have shown that high temperatures have a negative effect on human performance (Heal & Park,2016). Goodman et al. 2018 showed how exposure to high temperatures has negative long-term effects on students test scores in the USA. Park, 2018 showed the short-term effects of high temperatures on test scores of students in New York. Cho, 2017 focused on students in South Korea looking at the mid-term effects of heatwaves during summertime on test scores in fall.

Here, I want to contribute to the literature interested on the consequences of heatwaves on human capital accumulation. To do so, I test medium-term effects of heatwaves on children test scores in Italy.

In Italy, every year, students from 2nd 5th, 8th and 10th grade need to sit the test INVALSI. INVALSI is a representative national test that evaluates the student's abilities in Mathematics, Italian and English. However, for grade 2nd, 5th and 10th the test has low stakes. Conversely, for 8th graders the test affects the overall graduation grade from middle school. Therefore, the scores in the INVALSI test for 8th graders have high stakes as these affect the probability of graduating or not from middle school. Moreover, low grades in middle school might affect the probability of choosing an academic track or of getting accepted into the best high schools with consequences for future life outcomes.

In the last decade, the occurrence of heatwaves has been increasing in the days preceding the summer season in Italy. For example, May has been particularly hot in 2014 and 2016. Moreover, in 2017 has been registered the second hottest June from the Second World War. Based on previous research, days of extraordinary heat affect human capital accumulation of students influencing their test scores negatively (Cho,2017). Therefore, the research question I aim to answer is: How did the exposure to high temperatures in the spring months preceding the test affect scores of 8th graders in Italy?

Compared with the previous literature, my contribution is innovative for three main reasons. First, I estimate the effect of heatwaves focusing on the spring months preceding the test. Secondly, the analysis of the effect of high temperatures has not been yet tested in the European context and more specifically, on Italy. Thirdly, I consider heterogeneity based on socioeconomic status that to my knowledge has not been inquired yet. Understanding how heatwaves affect human capital accumulation in the spring months preceding the test and how the effect varies based on socioeconomic status is particularly important in Italy. The knowledge could permit to formulate policies to counteract the possible negative effects of extreme heat on test scores of vulnerable students.

Temperature and academic achievement

Recently, there has been increasing attention on the causes of climate change with a focus on the role of human activities. These affect the pace of climatic change and global warming with implications related to counteractive measures. Similarly, an emerging literature focuses on the consequences of climate change on human behaviour and health (Dell et al. 2014; Heal & Park,

2016). The rationale of this literature is to understand the impact of new environmental stressors emerging from climate change. Worrying questions emerge on the effects of global warming and the increase in the occurrence of heatwaves (Heal & Park,2016).
Some social groups are expected to suffer more from the negative effects of above-average temperatures. Therefore, heatwaves might exacerbate existing inequalities mostly affecting individuals with low socioeconomic status and minorities. Followingly, I will describe the research on heatwaves, human behaviour and the new climatic inequalities.

Heatwaves and effects on health and behaviour

The temperature of comfort for the human being is between 22°C to 24°C (Goodman et al. 2018). Variations from this temperature might induce stress, discomfort and environments with perceived heat higher than 32°C pose a concern for individuals. Heat has several negative effects on human beings as it disrupts sleep, generates heat stress and affects certain dimensions of human health and behaviour (Okamoto-Mizuno & Mizuno,2012; Heal & Park, 2016). The literature has shown how high temperatures increase aggressiveness and conflict (Heal & Park,2016). Moreover, heat increases depressive mood and the occurrence of suicide (Burke et al. 2018). About cognitive abilities, experimental studies have shown a negative effect of high temperature on performance (Seppanen et al. 2006; Kjellstrom et al. 2016). Research using observational data has exposed short-term, medium-term and long-term effects of heatwaves on educational attainment (Park,2016; Goodman et al.2018; Cho,2017; Graff Zivin et al. 2018). So, suggesting that high temperatures impair students' abilities during the day of the exam but also learning capacity during school days preceding a test. Therefore, heatwaves are negatively affecting the accumulation of human capital with negative consequences on student's educational attainment.

Inequalities and heterogeneity in the adaptation to climate change

Climate change and global warming have widespread consequences, but do not affect everyone equally. Heatwaves do not affect all citizens in the same fashion, as human adaptations and compensatory measures reduce its negative impacts (Graff Zivin et al.2018; Kahn, 2016). For example, individuals living in warmer cities are more equipped to cope with unpredictably high temperatures compared to citizens in relatively colder cities (Cho,2017; Behrer & Park,2017). In hot cities, individuals might be already equipped with air conditioning in their houses and adopt behaviours that limit the exposure to high temperatures. Also, some social groups are more vulnerable than others to heat. Especially, racial and socioeconomic differences are relevant factors affecting the extent to which individuals manage to cope with high temperatures (Gronlund, 2014; Albouy et al. 2016)). These differences depend on the variation in the quality of housing and neighbourhood characteristics. Poor individuals are less likely to possess air conditioning or to live in fresher areas of the city (Gronlund,2014; Goodman et al.2018). Moreover, vulnerable individuals might already suffer from physical or mental diseases that could be aggravated by heat stress (Gronlund,2014). In this regard, Taylor et al. 2018 showed how foreign-born US citizens have a higher mortality rate due to heat-related morbidity.
Considering cognitive abilities, high SES students are better equipped to affront heatwaves, as possessing air conditioning or living in fresher areas. Conversely, low SES students might be less able to limit the effects of extreme heat. Similarly, schools in already hot areas might be already equipped with air conditioning limiting the negative effects of high temperatures on educational attainment (Goodman et al. 2018). For this reason, macro and micro-level factors should be considered when

analysing the effect of heatwaves on educational attainment to control for adaptations and compensatory measures.
Having discussed the main literature, I will expose the dataset and main variables used in the empirical analysis.

Dataset and main variables

INVALSI test scores

In Italy, students in 2nd, 5th, 8th, 10th, 12th grade are required to sit the INVALSI test. From 2010 the test is used to have a national evaluation of the competencies attained by students. However, the test has high stakes only for the 8th graders. 8th graders are required to get access and sit an exam that when passed, permits to attend high school. From 2010 the overall graduation grade from middle school is also influenced by the score in the test INVALSI. The examination evaluates competences in Mathematics and Italian with a standardised test attended by all Italian students on the same day.
In my analysis, I will use data on the test scores of 8th graders from the year 2010 to 2017. The total sample comprises observations for eight years, with approximately 525,000 students for each cohort. In the table1 are exposed the dates of the exams. These are mostly taking place in the third week of June and starting at 8:30 in the morning. The data for the year 2018 is not considered as the test was sat in April and it did not have high stakes for the students. From 2018 the test if passed, permits to get access to the middle school exam but does not influence the graduation grade.

Tab.1 Test scores INVALSI from 2010 to 2017.

Year	Date of INVALSI test
2010	17 June
2011	20 June
2012	18 June
2013	17 June
2014	19 June
2015	19 June
2016	16 June
2017	15 June

Temperature

The period of exposure to high temperatures included in the analysis are the spring months before the test. Therefore, the period is from the 20th of March until the day preceding the exam. I exclude the date of the exam as the focus is on how the temperatures in the days preceding the test affect students' preparation. The spring months are usually mild in Italy with variations depending on the area of interest. However, the occurrence of heatwaves, especially in May and June, has been increasing in recent years. For example, in 2017 has been registered the hottest month of May in the world. In Italy, in this same year, occurred the second hottest summer registered after the second world war (the hottest was in 2003). The temperatures were high for the whole summer, but a peak was registered in June in the mid and end of the month. Also, May has been particularly warm in 2014 and 2016. Therefore, in the last decade, anomalously high temperatures in the spring months have been common in Italy.

In the analysis, I will use data from the "National Oceanic and Atmospheric Administration's Daily Global Historical Climatology Network". This dataset provides historical climatic data on several countries in the world and for Italy. The dataset permits to gather information on local temperatures using observations from local climatic stations from the 20th of March to the date of the exam for the years 2010 to 2017.

Dependent variable

The INVALSI test measures abilities in Mathematics and Italian using the Rasch model. In the analysis I used separately the standardized individual test scores for Mathematics and Italian as dependent variables.

Independent variable

To capture the exposure to heatwaves, I use a categorical variable with eight bins registering the number of days with maximum temperatures in the months preceding the test. The categories used in the variable are: <22°C, 22-24°C, 24-26°C, 26-28°C, 28-30°C, 30-32°C, 32-34°C and ≥ 34°C.

Empirical strategy

(1) $Yisct = \beta o + \sum_{j=1} \beta TEMPctj + \beta RAINct + HUMIDct + \alpha s + \gamma t + \varepsilon isct$

To capture the effect of heat waves on student's test scores, I compare different cohorts of students using school fixed effects and year fixed effects. $Yisct$ represents the score of a student i in the school s in the city c and the year t.
Previous research showed that high temperatures in the summer months preceding an examination had a negative effect on human capital accumulation (Cho,2017). Seemingly, high temperatures do not permit to effectively learn at home or school, reducing the amount of knowledge that students accumulate during the months preceding the test. So, the period of interest for this study are the spring months preceding the test. Therefore, I capture medium-term effects of heat with $TEMP$ a categorical variable that represents the number of days in which a maximum daily temperature was in the categories: <22°C, 22-24°C, 24-26°C, 26-28°C, 28-30°C, 30-32°C, 32-34°C and ≥ 34°C. For example, $\beta TEMPct5$ captures the number of days in which the maximum temperature was between 28-30°C.
Moreover, I introduce $RAIN$ and $HUMID$ to control for the possible effects of rain and humidity. High levels of humidity intensify the effects of heatwaves, increasing the perceived temperature. Conversely, rain lowers perceived heat reducing the effect of a heatwave. Also, αs and γt are introduced to account for school and year fixed effects. The standard errors are clustered at the city level, as error terms are expected to be correlated in the same city (Cho,2017).
In conclusion, I expect an extra day of high temperatures to influence students test scores exogenously. Therefore, using school and year fixed effects, I aim to capture the causal effect of heatwaves on educational attainment.

Heterogeneity by SES, gender and location

Having run the analysis on the pooled sample of students, I will then look at micro and macro-level differences. At the micro-level, I will consider differences based on student's SES and gender. Low SES students are expected to suffer more from the effect of an extra day of heat compared to high

SES students. I will consider gender differences as boys seem to suffer more from warmer environments, but the findings have been so far inconsistent (Cho, 2017). At the macro level, I will analyse the variation between “hot cities” and “cold cities”. Individuals living in “cold cities” should be less prepared to tackle extreme heat compared with citizens in “hot cities” (Cho,2017; Behrer & Park,2017). To do so, I calculate the summer mean temperatures in the years of analysis for the cities. Followingly, I register the variations from the summer mean temperature during the spring heatwave to define hot and cold cities. Arguably, citizens that are used to high temperatures during summertime would manage to cope better with unexpectedly high temperatures also in other times of the year. Therefore, the results should be stronger in “cold cities” rather than in “hot cities”.
To note is that Italian public schools lack air conditioning. So, heterogeneity at the micro and macro-level should be mostly determined by adaptive and compensatory behaviours taken individually in the student’s household.

References

Albouy, David & Graf, Walter & Kellogg, Ryan & Wolff, Hendrik (2016). "Climate Amenities, Climate Change, and American Quality of Life," Journal of the Association of Environmental and Resource Economists, University of Chicago Press, vol. 3(1), pages 205 - 246.

Burke, Marshall, Felipe González, Patrick Baylis, Sam Heft-Neal, Ceren Baysan, Sanjay Basu, and Solomon Hsiang. 'Higher Temperatures Increase Suicide Rates in the United States and Mexico'. Nature Climate Change 8, no. 8 (1 August 2018): 723–29. https://doi.org/10.1038/s41558-018-0222-x.

Cedeño Laurent, Jose Guillermo, Augusta Williams, Youssef Oulhote, Antonella Zanobetti, Joseph G. Allen, and John D. Spengler. 'Reduced Cognitive Function during a Heat Wave among Residents of Non-Air-Conditioned Buildings: An Observational Study of Young Adults in the Summer of 2016'. Edited by Jonathan Alan Patz. PLOS Medicine 15, no. 7 (10 July 2018): e1002605. https://doi.org/10.1371/journal.pmed.1002605.

Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 'What Do We Learn from the Weather? The New Climate-Economy Literature †'. Journal of Economic Literature 52, no. 3 (September 2014): 740–98. https://doi.org/10.1257/jel.52.3.740.

Heal, Geoffrey, and Jisung Park. "Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature." Review of Environmental Economics and Policy 10, no. 2 (2016): 1-17.

Kahn, Matthew E (2016), "The climate change adaptation literature." Review of Environmental Economics and Policy, 10, 166–178.

Kjellstrom, Tord, David Briggs, Chris Freyberg, Bruno Lemke, Matthias Otto, and Olivia Hyatt (2016), "Heat, human performance, and occupational health: a key issue for the assessment of global climate change impacts." Annual review of public health, 37, 97–112.

Goodman, Joshua and Hurwitz, Michael and Park, Jisung and Smith, Jonathan, Heat and Learning (2018). CESifo Working Paper No. 7291. Available at SSRN: https://ssrn.com/abstract=3338616

Graff Zivin, Joshua, Solomon M. Hsiang, and Matthew Neidell. 'Temperature and Human Capital in the Short and Long Run'. Journal of the Association of Environmental and Resource Economists 5, no. 1 (January 2018): 77–105. https://doi.org/10.1086/694177.

Gronlund C. J. (2014). Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. Current epidemiology reports, 1(3), 165–173. doi:10.1007/s40471-014-0014-4

Okamoto-Mizuno, K., & Mizuno, K. (2012). Effects of thermal environment on sleep and circadian rhythm. Journal of physiological anthropology, 31(1), 14. doi:10.1186/1880-6805-31-14

Park, Jisung. "Hot Temperature and High Stakes Exams: Evidence from New York City Public Schools (Job Market Paper)."(2018) Unpublished Manuscript, Harvard University Economics Department, Submitted

Randell, Heather, and Clark Gray. 'Climate Change and Educational Attainment in the Global Tropics'. Proceedings of the National Academy of Sciences 116, no. 18 (30 April 2019): 8840. https://doi.org/10.1073/pnas.1817480116.

Randell, Heather, and Clark Gray. 'Climate Variability and Educational Attainment: Evidence from Rural Ethiopia'. Global Environmental Change 41 (1 November 2016): 111–23. https://doi.org/10.1016/j.gloenvcha.2016.09.006.

Seppanen, Olli, William J Fisk, and QH Lei (2006), "Effect of temperature on task performance in office environment." Lawrence Berkeley National Laboratory.

Taylor, Ethel V., Ambarish Vaidyanathan, W. Dana Flanders, Matthew Murphy, Merianne Spencer, and Rebecca S. Noe. 'Differences in Heat-Related Mortality by Citizenship Status: United States, 2005–2014'. American Journal of Public Health 108, no. S2 (April 2018): S131–36. https://doi.org/10.2105/AJPH.2017.304006.