Journal of Environmental Economics and Management 83 (2017) 185–196

Contents lists available at ScienceDirect

Journal of Environmental Economics and Management

journal homepage: www.elsevier.com/locate/jeem

The effects of summer heat on academic achievement: A cohort analysis

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ARTICLE INFO

Article history:
Received 17 August 2016
Available online 28 March 2017

JEL classifications:
I2
Q54

Keywords:
Summer heat
Academic achievement
Test score
Compensatory behavior

ABSTRACT

This paper analyzed the effect of summer heat on academic achievement. Summer heat can negatively affect student learning, as previous studies have shown that high temperatures in laboratory settings have a negative effect on cognitive abilities. For this analysis, the test scores of five different cohorts were combined with city-level daily temperature data. To control for unobserved heterogeneity, the test scores of students within the same school were compared over time (school-fixed effects estimation). Summer heat negatively affected student test scores. Specifically, an additional day with a maximum daily temperature exceeding 34 °C (93.2 °F) during the summer, relative to a day with a maximum temperature between 28 °C (82.4 °F) and 30 °C (86 °F), decreased the scores of math and English tests by 0.0042 and 0.0064 standard deviations, respectively. No significant effects were found on the reading test scores. In addition, these effects were larger in relatively cooler cities, but did not differ based on gender. Finally, the previous year's summer also had negative effects on the current year's test scores.

Introduction

Climate change, along with its impact on human life, has become a topic of great interest to policy-makers and the general public. Human activity is a significant contributor to climate change since it increases the emission of greenhouse gases such as carbon dioxide and methane (Intergovernmental Panel on Climate Change (IPCC), 2007). A consequence of greenhouse gas emission is an increase in the ambient temperature of the earth as these gases absorb and emit radiation in the thermal infrared range, trapping the heat in the atmosphere. The IPCC (2014) found that the global emission of carbon dioxide in 2010 was twice than that of 1970.

Indeed, it is well documented that summers are becoming increasingly hot. For example, Della-Marta et al. (2007) found that the length of heat waves over western European countries doubled during the period 1880–2005 and the frequency of summer heat tripled. Habeeb et al. (2015) reported that the frequency, duration, and intensity of summer heat in 50 large U. S. cities increased significantly from 1961 to 2010. The 2003 European heat wave and the 2010 Russian heat wave are the two most recent well-known examples of hot summers.

Summer heat has been shown to have a negative effect on human health. Deschênes and Greenstone (2011) analyzed U.S. data from 1968 to 2002 and found that an additional day with a mean temperature exceeding 90 °F, relative to a day in the

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[1] This research was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2015S1A5A8018491) and the Yeungnam University Research Grant (215A580047). The author would like to thank Biung-Ghi Ju, Kichun Kang, Duol Kim, Chulseong Park, Kitae Sohn, and seminar participants at the Korean Labor Economic Association, Korean Applied Economic Association, and SIBR 2016 Osaka Conference for their valuable comments on this research.

http://dx.doi.org/10.1016/j.jeem.2017.03.005
0095-0696/

50–60 °F range, increased the annual age-adjusted mortality rate by about 0.1%. Barreca (2012) examined U.S. data from 1973 to 2002 and found that exposure to three additional days with temperatures exceeding 90 °F, relative to a day with temperatures between 60° and 70 °F, led to 0.54 additional deaths per 100,000 inhabitants. More than 70,000 people died in Europe during the summer of 2003 (e.g., Robine et al., 2008).

Summer heat also has the potential to negatively affect student learning, as studies have shown that high temperatures in laboratory settings had negative effects on cognitive abilities (e.g., Simmons et al., 2008; Gaoua et al., 2011; Schlader et al., 2015). These three studies used experimental setups in which each subject was exposed to both high and low temperatures for about 45 min each. High temperatures ranged from 45 °C to 50 °C, and a climatic chamber or water-perfused tube-lined suit was used to maintain the temperature level. Memory, attention, and accuracy were found to decrease with exposure to high temperatures.

The temperature-induced negative effects may be caused by decreasing cerebral blood flow (e.g., Drevets and Raichle, 1998; Ogoh et al., 2013; Bain et al., 2015) and increasing heat-related fatigue (e.g., McMorris et al., 2006; Nybo et al., 2014). Student learning may also be disrupted if they have to spend time to take care of family members who are sick from the summer heat. In addition, students could become sick from food poisoning, which occurs more frequently when the temperature is high (e.g., Bentham and Langford, 2001; Akil et al., 2014), or they may have sleep deprivation (e.g., Okamoto-Mizuno and Mizuno, 2012), resulting in increased errors during the daytime (e.g., Lim and Dinges, 2008).

Few studies have examined the relationship between summer heat and student academic achievement. Indeed, only one study by Graff Zivin et al. (2015) examined the effects of summer temperature on student test scores. The study evaluated the data collected in the National Longitudinal Survey of Youth (NLSY79), which consisted of information regarding people aged 14 to 22 in 1979. Starting in 1986, the Peabody Individual Achievement Tests (PIAT) was administered for children aged five or more of the women in the data between May and October each year. Analysis of about 24,000 observations of 8003 children (individual-fixed effect estimation) revealed that each degree day above 21 °C on the test day decreased the math score by 0.2 percentile points but had no effects on the reading test scores. No long-term effects were found on either test score. To calculate the long-term effects, the temperatures between successive tests and from children's birth were examined. Graff Zivin et al. attributed the absence of any long-term effects to parental compensatory behavior, in which parents spent more time or money to compensate for reduced learning caused by summer heat.

This paper contributes to the literature by being the second to analyze the effects of summer heat on student academic achievement. This paper differs from that of Graff Zivin et al. in several aspects. First, whereas Graff Zivin et al. termed the effects of test day temperature short-term effects and the effects of temperatures across all days between the tests long-term effects, this paper attempts to estimate medium-term effects. That is, this paper compliments the existing literature by estimating the effects of summer heat on the score of Korean college entrance exam taken in November.[2] Second, this paper conducts a cohort analysis with controlling for school-fixed effects. That is, this paper compares the test scores of five different cohorts who attend the same school. According to Hsiang (2016), a cohort analysis is a strengthening of the unit homogeneity assumption because different cohorts within a same unit are assumed to be comparable. Third, this paper analyzes a much larger sample: about 1.3 million observations over the five-year period from 2009 to 2013. The sample consists of high school seniors, and their college entrance exam scores are examined. About 3.2 million students took the test during the five years,[3] and the test scores of 50% of them, or about 1.6 million test takers, randomly selected with stratification are available to the public. Among them, first-time test takers or high school seniors are used for the analysis, and about 0.3 million test re-takers or high school graduates are excluded. Lastly, this paper conducts the following analyses according to different groups, which Graff Zivin et al. did not. The summer heat effect is examined by gender to check whether boys are affected more than girls, as previous studies (e.g., Deschênes and Greenstone, 2011; Bai et al., 2014) found that men are more likely to die from summer heat than women are. This study also examines whether students in cities with relatively cool summers are affected more than students in cities with relatively hot summers.

Since the test score data identify the city of each student's school, it is possible to merge the test score data with the temperature data.[4] This paper includes 1729 schools in 164 cities in the analysis, including Seoul and Busan, the two largest cities in Korea. In 2009, the first year of the study, there were 2225 high schools and 165 cities in Korea; thus, the sample represents the entire country. Each city in the analysis has an average of 8018 observations over the five years, while the median is 1753 observations. Seoul has the largest number of observations, 253,121, over the five years, followed by Busan with 91,107. Each school has an average of 760 observations over the five years, and the median is 667.

Summer heat had negative effects on student test scores. Specifically, an additional day with a maximum daily temperature exceeding 34 °C during the summer, relative to a day with a maximum temperature between 28 °C and 30 °C, decreased the scores of math and English tests by 0.0042 and 0.0064 standard deviations, respectively. No significant effects were found on the reading test scores. This paper conducted a placebo test to examine whether the next year's summer temperature affected the current year's test scores and found no such evidence. In addition, these effects were larger in relatively cooler cities, but did not differ based on gender. Lastly, the previous year's summer also had negative effects on the current year's test scores.

[2] The Korean school year starts in March and ends in February, with a summer break running from mid-July to mid-August.

[3] From 2009 to 2013, 638,216, 668,991, 648,946, 621,336, and 606,813 students took the test, respectively.

[4] The use of temperature measured at the closest station from each school is more ideal, but cannot be used because the school identity is not available.