Too Hot or Too Cold to Study? The effect of temperature on student time allocation

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Too Hot or Too Cold to Study?
The effect of temperature on student time allocation

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Abstract

This paper studies the causal effect of temperature on students' time use for both college and high school students. Students substitute study time with leisure on days with extremely low and high temperatures. Extreme temperatures also have a noticeable heterogeneous effect on time allocation for both groups of students. College students respond to the unpleasant weather by substituting study time with weather-appropriate leisure. In comparison, high school students reduce both class and self-study time, which is more frequent during cold days. Lastly, students in cold and hot climates are observed to react more to the temperature to which they are not acclimatized. Our findings offer a different perspective by uncovering the black box behind the relationship between weather and test scores seen in recent literature.

JEL: I2 Q5

Keywords: temperature; allocation of time; educational activities; leisure

Highlights

- This study is the first to unveil a leisure-education trade-off as a result of temperature change.
- We find robust evidence that curriculum and the local climate play a vital role in determining how students utilize their time when the temperature moves toward both tails of the distribution.
- Students are more reactive to the temperature to which they are not acclimatized (e.g., Hot day in a cold area).

1 Introduction

Although academic performance is a strong predictor of lifetime income (Crawford et al., 1997), the issue of how environmental factors, such as changes in temperature, influence the decision to study is still not well understood. Comprehending how these external conditions affect study time, the most fundamental input in the education production function, is critical since increasing study time leads to better grades (Keith, 1982). This question is even more relevant at the juncture of intensified climate changes as a result of global warming.

To the best of our knowledge, this study is the first to unveil a causal relationship between temperature and student time allocation. We find that relative to the local climate's normal weather conditions, days with temperatures exceeding the bottom and top twentieth percentile lead to reduced academic activities for both high school and college students. The forgone study time is reallocated towards leisure activities. Furthermore, the substitution between education and leisure depends on the direction of the extreme weather. The reduction in study time is reallocated to indoor activities on frigid days and allocated to activities that require travel or are performed outdoors on days with intense heat.

In addition, we find robust evidence that both the curriculum and the local climate play a vital role in determining how students utilize their time when the temperature moves toward both tails of the distribution. Empirical results suggest that during periods with undesirable temperature, the loss of self-study time for high school students coincides with the loss of class time. In contrast, evidence indicates that college students respond through a different mechanism wherein they adjust their self-study time to a more considerable degree during periods when the temperature is sweltering. This could be ascribed to their flexible curriculum, which allows them to apportion time according to the opportunity costs associated with leisure activities. Finally, we observe that the choices regarding college students' time use are affected by the local climate wherein these students respond tremendously to temperatures they are not acclimatized.

This study is related to two strands of literature. First, several studies have documented the substantial relationship between students' test scores and heatwaves (see Park et al., 2020; Zivin et al., 2020). However, it is difficult to identify whether the observed adverse effects are the outcome of the decline in the quantity (length) or the quality of the study, given that these consequences can be caused either by the reduction in students' time allocation in educational activities or by the worsened cognitive performance during severe weather conditions (Park, 2020). Instead of capturing the combined effect of the two mechanisms, such as in Park et al. (2020), the time-use data allows us to identify the "quantity" channel alone by examining the time devoted to academic activities. Thus, our analysis provides a different perspective and potentially opens the black box behind the relationship between weather and test scores observed in the recent literature. Second, this study adds to a small but increasing literature on how temperature affects peoples' productive time use (such as Graff Zivin and Neidell, 2014; Jiao et al., 2021), given that there has been no study examining the time allocation of students and their response to exogenous temperature changes in the past. Hence, our study enhances the understanding of adolescents' time allocation and provides an insight into an essential and unexplored channel through which human capital development may be influenced.

2 Data and Estimation Strategy

2.1 Data

We base our analyses on the American Time Use Survey (ATUS, see for details: bls.gov/tus).[4] Our sample covers the years 2004 to 2017 and we restrict our sample to individuals who are enrolled in high school or college at the time of the survey. Furthermore, we limit our sample to survey days conducted during spring and fall, seasons when classes typically occur. To gain a better understanding of the time allocation of students, we classify their activities into four categories: (1) class time, (2) self-study, (3) leisure, and (4) all other activities. Class time includes attending class and administrative activities. Self-study comprises homework, extra-curricular activities, and other education-related activities. Finally, leisure consists of activities like personal care activities, shopping, eating, drinking, socializing, and exercising.[5] The contents of each category and the corresponding ATUS code can be found in Appendix Table A1.

Additionally, we obtain our meteorological data from the National Climatic Data Center (NCDC, see for details: ncdc.gov). To calculate the daily temperature by county, we use the Inverse Distance Weighting (IDW) method, wherein we take the weighted average of the valid measures from all weather stations located in a county. The weights we apply are based on the inverse distance of a station to the centroid of a county.[6]

[4] The ATUS records the time-use, in minutes, of all activities from 4:00 a.m. of the designated diary date up to 3:59 a.m. of the following day. The respondents in the ATUS are aged 15 and older who are randomly drawn from households in the Current Population Survey (CPS).

[5] The activities in the ATUS which are classified as part of personal care include activities such as sleeping, grooming, and health-related self-care.

[6] For counties that do not have any weather stations and thus, have no weather data, we use the observed data from the nearest weather station outside the county's border. For other weather elements, we take the average of the valid observations from all weather stations within a county.

Our final sample contains 2,561 high school and 2,556 college students. Table A2 in the Appendix details the descriptive statistics of all variables in the sample. The average age for high school and college students is approximately 17 and 26 years old, respectively, with the entire sample consisting of 75.2% white and 52.3% female students. On average, a high school student spends 288.9 minutes on class and self-study and 975.2 minutes on leisure activities per day. In contrast, the daily time spent on all educational activities and leisure of a typical college student is 177.9 and 883.3 minutes, respectively.

2.2 Empirical Specifications

Considering the students' behavior and time allocation are primarily determined by the course curriculum's design and flexibility, we split the sample by college and high school and estimate the following econometric model:

$$Y_{icdy} = \alpha + \beta_1 Cold_{cdy} + \beta_2 Hot_{cdy} + \theta X_{icdy} + \eta Z_{cdy} + Weekend_{idy} + Fall_{idy} + \phi_y + \gamma_c + \epsilon_{icdy}. \quad (1)$$

Where Y_{icdy} corresponds to both the participation (or likelihood) and the amount of time spent (in minutes) in an activity by student i in county c, on date d of year y. $Cold_{icdy}$ (Hot_{icdy}) is an indicator variable that is equal to one if the maximum temperature in county c on date d is lower (greater) than the 20th (80th) percentile of the historical county temperature distribution from 2004 to 2017 and zero otherwise. As compared to actual temperatures, our measure is more suitable for studying an individual's response to temperature because a 90-degree day could be perceived differently by a resident from Miami, Florida versus one from Chicago, Illinois. This argument is further strengthened by our differential findings when students are divided according to the local climate. Moreover, using a relative temperature measure is more appropriate for examining the potential effects of climate change since the climatological literature indicates that the temperature shift from climate change could manifest as a shift relative from their typical weather conditions (Sherwood et al., 2020), which is the type of effect captured in this paper.

Our estimates could be contaminated by selective migration. Individuals, especially college students, may choose to avoid a location with an undesirable climate. To mitigate this concern, we control for two types of average local migration probability among college students. Specifically, these are probabilities of cross-state migration since birth and cross-county migration for the past year.[7]

[7]The migration data is from the Census Bureau and IPUMS. For each county and year, we measure the average college student migration propensity from the past year and since birth. As a result, the college sample only includes observations from 2005 to 2017 because no migration information is available for 2004. For the high school sample, we do not control for migration rates because very few students frequently change their

X_{icdy} includes individual characteristics like age, race, and gender. Z_{cdy} are the other weather variables for county c at date d of year y, which comprise precipitation, snowfall, wind speed, and humidity indicators.[8] $Weekend_{idy}$ and $Fall_{idy}$ are dummies indicating if the respondent was surveyed during the weekend and the Fall season. Finally, ϕ_y are the year fixed effects and γ_c are the county fixed effects, which controls for temporal and geographical patterns in student composition and behavior. In the analyses, the standard errors are clustered by county and the ATUS sampling weights are applied.

3 Results

3.1 Baseline Results

Table 1 displays the results of the primary specification for college and high school students wherein several findings emerge. Firstly, extreme temperatures, regardless of cold or hot, can induce an education-leisure trade-off whereas time spent on all other activities shows no response to such weather extremes. This trade-off holds for both high school and college students. Such leisure and education substitution is supported by Connolly (2008), which asserted that an individual optimally chooses the amount of leisure and work or productive activities which will maximize his or her utility conditional on the time constraint. In our context, the marginal rate of substitution between leisure and education could alter with temperature. For example, extreme weather, which is damaging to an individual's productivity (Cai et al., 2018) and is detrimental to students' cognitive skills (Park, 2020), could reduce the marginal utility from study. However, the marginal utility from leisure may increase during such intense temperatures. Therefore, students are more likely to decrease education time and increase leisure.

Secondly, the heterogeneous effects of temperature among students are remarkable. College students tend to reduce class attendance and class time on cold days and they also decrease their involvement and time allocation on self-study during scorching days. Specifically, frigid days reduce their probability of attending class by 9.7 percentage points and their time allocation on in-class activities by 27.43 minutes, which accounts for 28.96% and 36.27% of the mean, respectively. Meanwhile, sweltering days decrease the probability of college

locations (Park et al., 2020).

[8] The humidity data is from Copernicus, the European Union's Earth observation program. Humidity indicators are dummy variables indicating whether a county has an uncomfortably high or low level of humidity on a given month. High and low humidity are defined by the recommended values of the Occupational Safety and Health Administration (OSHA), which states an average relative humidity of less than 30% or greater than 60% as noticeably uncomfortable. Details of the humidity classification can be found here, osha/occupation).

Table 1: The Effect of Extreme Temperature on Student Time Allocation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Education				Leisure	All Other	Subcategories of Leisure	
	Class Time		Self-study			Activities	Indoors	Outdoors
	(Prob.)	(Minutes)	(Prob.)	(Minutes)	(Minutes)	(Minutes)	(Minutes)	(Minutes)
Panel A. College Students								
Cold Days	-0.097**	-27.432**	-0.029	-10.014	26.806	-12.872	38.962*	-12.156
	(0.043)	(11.251)	(0.046)	(11.570)	(19.458)	(23.796)	(20.156)	(8.193)
Hot Days	-0.088*	-20.481	-0.139**	-45.107***	61.212**	4.302	25.567	35.645*
	(0.049)	(13.154)	(0.057)	(16.057)	(24.946)	(19.947)	(24.037)	(19.472)
Observations	2556	2556	2556	2556	2556	2556	2556	2556
R^2	0.344	0.304	0.199	0.192	0.325	0.298	0.286	0.204
Panel B. High School Students								
Cold Days	-0.086**	-30.542*	-0.130***	-14.665**	35.753*	-0.576	34.646**	1.108
	(0.037)	(16.253)	(0.049)	(7.429)	(18.795)	(14.554)	(15.493)	(12.507)
Hot Days	-0.006	-0.293	-0.002	6.545	5.833	-10.531	0.586	5.247
	(0.033)	(13.239)	(0.042)	(8.702)	(17.789)	(12.389)	(19.596)	(12.202)
Observations	2561	2561	2561	2561	2561	2561	2561	2561
R^2	0.613	0.595	0.214	0.181	0.386	0.253	0.307	0.185
Panel C. P-value of Chow Tests between College and High School								
Cold Days	0.650	0.815	0.204	0.774	0.945	0.748	0.748	0.498
Hot Days	0.189	0.281	0.082	0.001	0.095	0.373	0.519	0.072

Notes: Table 1 reports the effect of temperature on the likelihood of participating in different categories as well as the amount of time spent (in minutes) on those activities for college and high school students separately. The results are estimated by Eq. 1 and weighted by the ATUS weights. The standard errors clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1.

students' performing self-study activities by 27.47% and 44.12% of the mean. Furthermore, heatwaves seem to have a more substantial effect on study time. Nevertheless, we find that reduction in the time allocation for education is substituted by an increase in leisure during extreme temperatures.

Conversely, high school students respond to temperature through a different mechanism. Their time allocation decision regarding self-study seems to be tied to class meetings wherein their time spent on out-of-class activities is significantly lower during cold weather when the probability of attending class is also declining. Particularly, a frigid day reduces a high school student's participation in class and self-study by approximately 8.6 and 13.0 percentage points, which account for 14.48% and 25.79% of the mean values, respectively. Additionally, in terms of changes in time allocation, a cold day reduces a high school student's time use on in-class activities and homework by 13.58% and 22.93% of the mean. However, the education-leisure trade-off is not observed for high school students on hot days.

Such findings, specifically for low-temperature days, can be explained by the fact that most school cancellations in the US occur during cold snow days.[9] Additionally, the decline in self-study time for high school students on chilly days is observed to coincide with the reduction in class time, suggesting that the two types of educational activities are associated with each other. In contrast, on hot days when class cancellations typically do not occur, the more salient substitution effect between leisure and self-study for college students reflects their more flexible curriculum in comparison to high school students.

Thirdly, we further test in the last panel of Table 1 the difference in point estimates between high school and college students. Time allocation for self-study, leisure, and leisure activities that are performed outdoors or require travel are significantly different across the two groups of students on days with scorching temperatures, indicating that separating the entire sample into college and high school students is necessary for our analysis.

Finally, in the last two columns, we investigate how students reallocate their time to different leisure activities whenever study time decreases. We closely examine each of the main and the second tier of ATUS activity categories and divide leisure time into two, namely, activities performed at home or indoors and activities that require travel or performed outdoors. Our classification of outdoor and indoor leisure is listed in Appendix Table A3. Both college and high school students respond to hot and cold weather by reducing their education time with weather-appropriate leisure. Particularly, indoor activities, which include sleeping, watching television, and playing video games, are favored on cold days. Whereas, outdoor activities, which include attending events, visiting museums, shopping, and playing sports, are more likely to occur for college students on hot days.[10]

3.2 Robustness Checks and Heterogeneity Analysis

In the baseline results, a cold (hot) day occurs when the temperature falls below (rises above) the bottom (top) 20^{th} percentile of the local temperature distribution.[11] We further test if our results are robust to alternative definitions of extreme days. As shown in Figure 1, extreme temperatures are identified using different percentile bins. The effect of each extreme

[9] In an analysis by Wong et al. (2014) of 20,723 unplanned school closures from August 1, 2011 to June 30, 2013, 79% are due to weather events with these weather-related closures occurring the most during winter (64%) and spring (32%).

[10] We show that our results are not driven by the behavioral difference during weekdays and weekends in Appendix Table A4 by removing the observations reported on weekends. The results from the weekday sample are consistent with the results from our main table.

[11] The mean temperatures of cold and hot days in our baseline definition are $9.56°C$ ($49.21°F$) and $31.57°C$ ($88.82°F$), respectively.

temperature bin is calculated in reference to days with temperature between the 30^{th} and 70^{th} percentile. The results of self-study are displayed in Figure 1 and it suggests that, as the weather becomes more extreme, the education-leisure trade-off increases.[12]

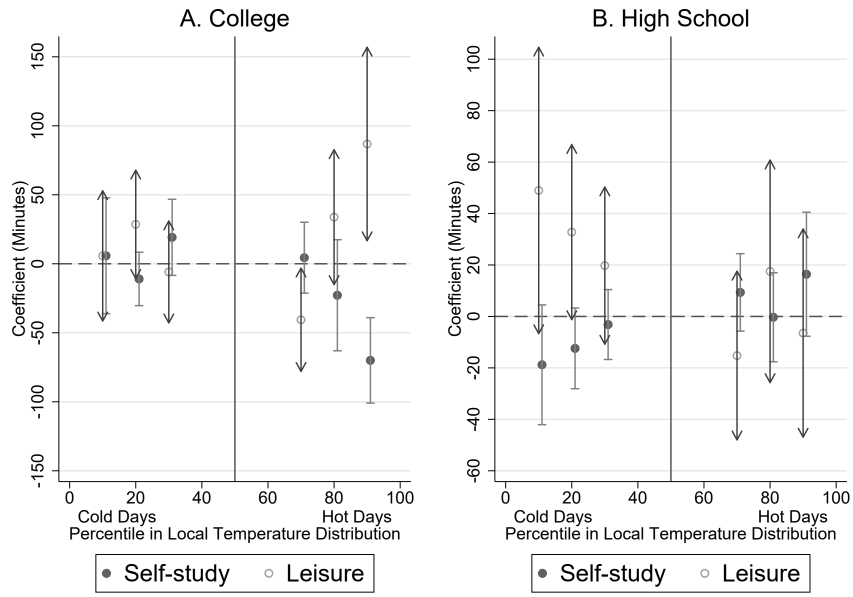

Figure 1: Temperature's Effect on High School and College Students' Time Allocation on Self-study and Leisure

Note: The points and error bars depict the changes in time allocation, relative to days with temperatures in between the 30^{th} and 70^{th} percentile, as wells as the 90% CI resulting from using the following percentile bins: less than 10, 10-20, 20-30, 70-80, 80-90, and greater than 90. The results are obtained by estimating Equation 1 using the sampling weights provided in the ATUS and with the standard errors clustered by county.

Figure 2 explores if college students living in cold (hot) places would be less tolerant of the heat (frigid weather). We divide the states into intrinsically cold and hot areas. A state is defined as a place with a cold (hot) climate when its temperature over the warmest months, from June to September, falls into the bottom (top) 30^{th} percentile of the distribution of the temperature of all the states.[13] In Appendix Table A5, we also test the significance of the differences between hot and cold places. The results show that frigid weather significantly reduces time allocation in education for students living in hot places. Meanwhile, study time for those residing in cold places declines more substantially when the temperature becomes exceedingly high.[14]

[12]We focus on self-study since it is more flexible than the highly rigid class time. Thus, students are more likely to make adjustments in response to weather changes.

[13]Our results are robust to varying definitions of hot and cold places. Results are available upon request.

[14]We present the results for college students who have a more flexible curriculum and more choices of allocation education time adjusting to different weathers.

Similarly, as shown in Figure 2, college students from both cold and hot climates react more to the temperature to which they are not acclimatized. For instance, students from cold places spend about 180 minutes less time learning during a sweltering day (85^{th} percentile or higher) than a day with mild temperature. Our findings of students' limited adaptation to extreme temperatures lend some support to other studies (such as Adger et al., 2009; Graff Zivin and Neidell, 2014), indicating that people are more responsive to the temperature they are not used to. However, given the inherently limited data, our results should be interpreted with caution and be viewed as suggestive evidence of poor adaptation in the short run.

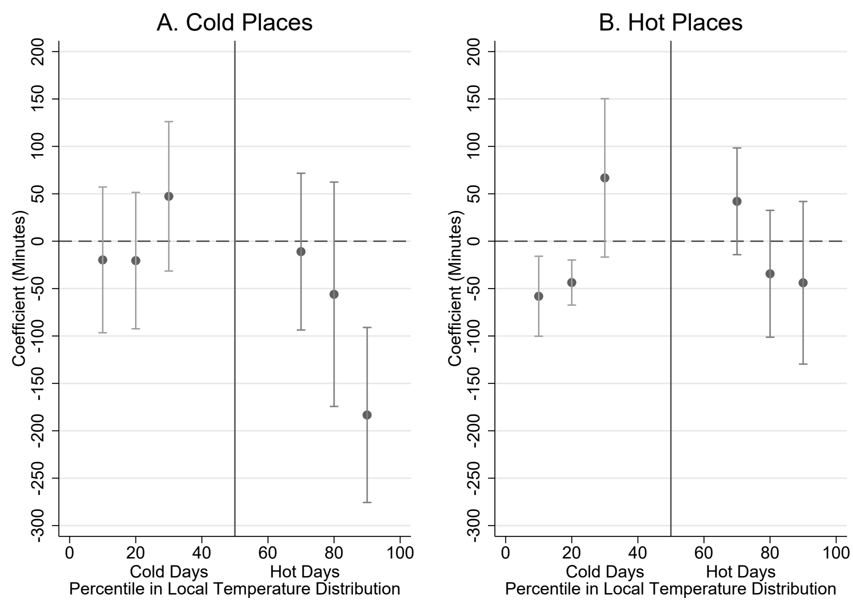

Figure 2: Temperature's Effect on College Students' Time Allocation on Total Education

Note: The points and error bars along the graph depict the coefficients, in minutes, of the adjustments due to temperature. The results are plotted following the alternative definitions of extreme temperatures used in Figure 1. Cold (Hot) places are defined as places where the temperature during the hottest months of the year are below (above) the 30^{th} (70^{th}) percentile temperature of all the states.

4 Discussion and Conclusion

This paper sheds light on how temperature influences student time allocation. First, our findings on the adverse impacts of unfavorable temperature on students' study time suggest a novel channel that extreme weather may have on human capital accumulation. An essential factor in the accretion of human capital is study time and extreme temperatures could temporarily interrupt students' learning by reducing their class attendance and self-study. This is also even more critical since climate change is not only responsible for the rising average temperatures but also for more frequent temperature extremes (Vose et al., 2017). Second, our study complements other literature which focused on heatwaves and test scores of high school students. Test grades are a function of both test day cognitive performance as well as the cumulative study time. However, in our study, high school students do not reduce their study time on hot days suggesting that lower grades on hot exam days could be primarily driven by the cognitive performance channel, which stipulates that exposure to heat will diminish attention, memory, information retention and processing, and the performance of psycho-perceptual tasks (Hocking et al., 2001).

References

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., Naess, L. O., Wolf, J. and Wreford, A. (2009), 'Are there social limits to adaptation to climate change?', *Climatic change* **93**(3), 335–354.

Cai, X., Lu, Y. and Wang, J. (2018), 'The impact of temperature on manufacturing worker productivity: evidence from personnel data', *Journal of Comparative Economics* **46**(4), 889–905.

Connolly, M. (2008), 'Here comes the rain again: Weather and the intertemporal substitution of leisure', *Journal of Labor Economics* **26**(1), 73–100.

Crawford, D. L., Johnson, A. W. and Summers, A. A. (1997), 'Schools and labor market outcomes', *Economics of Education Review* **16**(3), 255–269.

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

Hocking, C., Silberstein, R. B., Lau, W. M., Stough, C. and Roberts, W. (2001), 'Evaluation of cognitive performance in the heat by functional brain imaging and psychometric testing', *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* **128**(4), 719–734.

Jiao, Y., Li, Y. and Liu, M. (2021), 'Widening the gap? temperature and time allocation between men and women', *Applied Economics* **53**(5), 595–627.

Keith, T. Z. (1982), 'Time spent on homework and high school grades: A large-sample path analysis.', *Journal of educational psychology* **74**(2), 248.

Park, R. J. (2020), 'Hot temperature and high stakes performance', *Journal of Human Resources* .

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

Sherwood, S., Webb, M. J., Annan, J. D., Armour, K., Forster, P. M., Hargreaves, J. C., Hegerl, G., Klein, S. A., Marvel, K. D., Rohling, E. J. et al. (2020), 'An assessment of earth's climate sensitivity using multiple lines of evidence', *Reviews of Geophysics* **58**(4), e2019RG000678.

Vose, R. S., Easterling, D. R., Kunkel, K. E., LeGrande, A. N. and Wehner, M. F. (2017), *Temperature changes in the United States*, Climate Science Special Report: Fourth National Climate Assessment, Volume I, U.S. Global Change Research Program, Washington, DC, USA, pp. 185–206. 29960c69-6168-4fb0-9af0-d50bdd91acd3.

Wong, K. K., Shi, J., Gao, H., Zheteyeva, Y. A., Lane, K., Copeland, D., Hendricks, J., McMurray, L., Sliger, K., Rainey, J. J. et al. (2014), 'Why is school closed today? unplanned k-12 school closures in the united states, 2011–2013', *PLoS One* **9**(12), e113755.

Zivin, J. G., Song, Y., Tang, Q. and Zhang, P. (2020), 'Temperature and high-stakes cognitive performance: evidence from the national college entrance examination in china', *Journal of Environmental Economics and Management* **104**, 102365.

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Appendix

Table A1: Activity Categories

Category	Subcategory	Activity	ATUS Activity Code
Education	Class Time	Taking Class	0601XX
		Registration/Administrative Activities	0604XX
	Self-study	Extracurricular School Activities (Except Sports)	0602XX
		Research/Homework	0603XX
		Education, not elsewhere classified	0699XX
Leisure		Personal Care Activities	01XXXX
		Consumer Purchases	07XXXX
		Eating and Drinking	11XXXX
		Socializing, Relaxing, and Leisure	12XXXX
		Sports, Exercise, and Recreation	13XXXX
		Telephone Calls	16XXXX
Others		Government Services and Civic Obligations	10XXXX
		Religious and Spiritual Activities	14XXXX
		Volunteer Activities	15XXXX
		Medical and Care Services	0804XX
		Household Activities	02XXXX
		Caring for and Helping Household Members	03XXXX
		Caring for and Helping Nonhousehold Members	04XXXX
		Work and Work-Related Activities	05XXXX
		Professional and Personal Care Services	0801XX
		Financial Services and Banking	0802XX
		Legal Services	0803XX
		Personal Care Services	0805XX
		Real Estate	0806XX
		Veterinary Services (excluding grooming)	0807XX
		Security Procedures Related to Professional/Personal Services	0808XX
		Professional and Personal Services, not elsewhere classified	0899XX
		Household Services	09XXXX
		Travelling	18XXXX

Table A2: Summary Statistics

	Full Sample		High School		College	
	N = 5,117		N = 2,561		N = 2,556	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Panel A: Time Use Variables						
Class Time	150.225	184.425	224.906	199.295	75.642	131.111
Self-study	83.101	127.556	63.951	97.904	102.226	149.068
Leisure	929.231	236.986	975.180	229.018	883.342	235.959
All Other Documented Activities	260.469	227.220	162.581	154.320	358.229	245.546
Indoor Leisure	827.369	221.212	862.142	218.856	792.642	218.116
Outdoor Leisure	101.861	127.165	113.038	129.770	90.699	123.528
Class Time Dummy	0.464	0.499	0.594	0.491	0.335	0.472
Self Study Dummy	0.505	0.500	0.504	0.500	0.506	0.500
Panel B: Control Variables						
Age	21.384	7.473	16.597	2.434	26.164	7.745
White	0.752	0.432	0.755	0.430	0.748	0.434
Female	0.523	0.500	0.471	0.499	0.575	0.494
Year	2010.831	3.819	2010.645	3.889	2011.017	3.740
Fall	0.513	0.500	0.500	0.500	0.526	0.499
Weekend	0.286	0.452	0.281	0.450	0.290	0.454
High School Dummy	0.500	0.500	1.000	0.000	0.000	0.000
Birth Migration	0.439	0.140	0.433	0.136	0.443	0.144
County Migration	0.120	0.059	0.115	0.055	0.124	0.063
Panel C: Weather Variables						
Survey Day Maximum Temperature	69.039	15.204	69.445	15.369	68.633	15.030
Cold Days Temperature Cutoff	52.889	12.483	53.261	12.678	52.518	12.277
Hot Days Temperature Cutoff	85.348	6.769	85.537	6.770	85.160	6.764
Cold Days Dummy	0.099	0.299	0.103	0.304	0.095	0.294
Hot Days Dummy	0.081	0.273	0.089	0.285	0.074	0.261
Precipitation	2.469	7.104	2.439	6.895	2.498	7.309
Snowfall	0.883	8.626	0.932	7.994	0.834	9.215
Wind Speed	3.352	1.640	3.351	1.617	3.354	1.663
Low Humidity Dummy	0.028	0.164	0.027	0.162	0.028	0.166
High Humidity Dummy	0.713	0.452	0.697	0.460	0.729	0.445
Missing Humidity Dummy	0.050	0.218	0.036	0.187	0.063	0.244

Notes: All variables presented in the summary statistics are weighted using the ATUS sampling weights. The time use dummy variables are equal to one if the time use for the category is positive while time use variables that are not dummies are in minutes and include observations with zero values. Survey day maximum temperature is a variable that indicates the temperature for each county for the designated survey day. Cold (Hot) Days Dummy refers to our baseline definition and is equal to one if the temperature during the survey day lies below (above) the 20th (80th) percentile of the local temperature distribution. Precipitation is reported in millimeters (volume/area). Snowfall is measured in inches and wind speed is measured in meters per second. Data source: 2004-2017 American Time Use Survey, National Climatic Data Center meteorological data, and Copernicus humidity data.

Table A3: Categories of Leisure

Category	Activity	ATUS Activity Code
	Sleeping	0101XX
	Grooming	0102XX
	Health-related self Care	0103XX
	Personal Activities	0104XX
	Personal care, n.e.c.	0199XX
	Relaxing and Thinking	120301
	Tobacco and drug use	120302
	Television and movies (not religious)	120303
	Television (religious)	120304
	Listening to the radio	120305
	Listening to/playing music (not radio)	120306
	Playing games	120307
	Computer use for leisure (exc. Games)	120308
	Arts and crafts as a hobby	120309
Indoors	Collecting as a hobby	120310
	Hobbies, except arts & crafts and collecting	120311
	Reading for personal interest	120312
	Writing for personal interest	120313
	Relaxing and leisure, n.e.c.	120399
	Telephone Calls	16XXXX
	Personal Care Emergencies	0105XX
	Researching purchases, n.e.c.	070299
	Security Procedures Related to Consumer Purchases	0703XX
	Consumer Purchases, n.e.c.	0799XX
	Eating and drinking	110101
	Waiting associated with Eating & Drinking	1102XX
	Eating and drinking, n.e.c.	110199
	Eating and drinking, n.e.c.	119999
	Socializing, relaxing, and leisure, n.e.c.	129999
	Grocery shopping	070101
	Purchasing gas	070102
	Purchasing food (not groceries)	070103
	Shopping, except groceries, food and gas	070104
	Waiting associated with shopping	070105
	Shopping, n.e.c.	070199
	Comparison shopping	070201
	Socializing and communicating with others	120101
	Socializing and communicating, n.e.c.	120199
	Attending or hosting parties/receptions/ceremonies	120201
	Attending meetings for personal interest (not volunteering)	120202
	Attending/hosting social events, n.e.c.	120299
Outdoors	Attending performing arts	120401
	Attending museums	120402
	Attending movies/film	120403
	Attending gambling establishments	120404
	Security procedures rel. to arts & entertainment	120405
	Arts and entertainment, n.e.c.	120499
	Waiting associated with Socializing, Relaxing, and Leisure	1205XX
	Participating in Sports, Exercise, and Recreation	1301XX
	Attending Sports/Recreational Events	1302XX
	Waiting Associated with Sports, Exercise, & Recreation	1303xx
	Security Procedures Related to Sports, Exercise, & Recreation	1304xx
	Sports, Exercise, and Recreation, n.e.c.	1399xx

Table A4: Weekday Subsample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Education				Leisure	All Other	Subcategories of Leisure	
	Class Time		Self-study			Activities	Indoors	Outdoors
	(Prob.)	(Minutes)	(Prob.)	(Minutes)	(Minutes)	(Minutes)	(Minutes)	(Minutes)
Panel A. College Weekdays								
Cold Days	-0.136*	-40.805**	-0.041	-6.401	10.146	2.418	17.061	-6.915
	(0.077)	(19.007)	(0.070)	(15.390)	(29.738)	(34.106)	(31.126)	(11.535)
Hot Days	-0.097	-16.593	-0.164**	-53.874***	48.036	27.306	5.673	42.364
	(0.071)	(19.517)	(0.079)	(20.644)	(36.518)	(28.690)	(33.899)	(29.264)
Observations	1272	1272	1272	1272	1272	1272	1272	1272
R^2	0.316	0.312	0.287	0.273	0.307	0.376	0.299	0.255
Panel B. High School Weekdays								
Cold Days	-0.139**	-53.819**	-0.193***	-19.434*	58.535**	-2.869	44.890**	13.645
	(0.054)	(21.990)	(0.068)	(9.983)	(28.043)	(20.986)	(22.134)	(17.608)
Hot Days	0.005	-0.417	0.036	13.360	3.624	-15.488	2.972	0.652
	(0.050)	(19.932)	(0.059)	(10.718)	(22.931)	(14.746)	(25.157)	(15.822)
Observations	1267	1267	1267	1267	1267	1267	1267	1267
R^2	0.280	0.305	0.289	0.279	0.297	0.343	0.286	0.237

Notes: Table A4 reports the effect of temperature on the likelihood of participating in different categories as well as the amount of time spent, in minutes, on those activities for college and high school students separately during weekdays. For other details, see Table 1 in the main text. *** p<0.01, ** p<0.05, * p<0.1.

Table A5: Heterogeneous Effect of Temperature for Cold vs Hot Places

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	College				High School			
	Class Time		Self-study		Class Time		Self-study	
	(Prob.)	(Minutes)	(Prob.)	(Minutes)	(Prob.)	(Minutes)	(Prob.)	(Minutes)
Cold Days	-0.235***	-52.953**	0.015	-17.137	-0.039	-0.889	-0.173	-22.608
	(0.086)	(25.255)	(0.110)	(28.122)	(0.092)	(38.547)	(0.125)	(18.310)
Hot Days	-0.088	-9.497	-0.076	-40.852	0.067*	37.285*	0.108	29.340*
	(0.126)	(35.134)	(0.143)	(30.933)	(0.040)	(19.506)	(0.075)	(17.023)
Cold Days x Cold Places	0.473***	38.139	0.326**	14.469	0.085	33.325	0.082	27.729
	(0.171)	(36.516)	(0.133)	(38.600)	(0.117)	(52.348)	(0.168)	(20.473)
Hot Days x Cold Places	-0.021	-31.978	-0.428**	-86.063*	-0.053	-20.506	0.002	-31.903
	(0.188)	(52.877)	(0.203)	(45.128)	(0.104)	(43.869)	(0.160)	(36.410)
Observations	1683	1683	1683	1683	1742	1742	1742	1742
R^2	0.318	0.290	0.205	0.189	0.604	0.585	0.200	0.180

Notes: Table A5 reports the effect of temperature on the likelihood of participating in class time and self-study as well as the amount of time spent, in minutes, on those activities for college and high school students separately during the coldest days (temperatures less than the 10^{th} percentile) and the hottest days (greater than 90^{th} percentile). For other details, see Table 1 in the main text. *** p<0.01, ** p<0.05, * p<0.1.