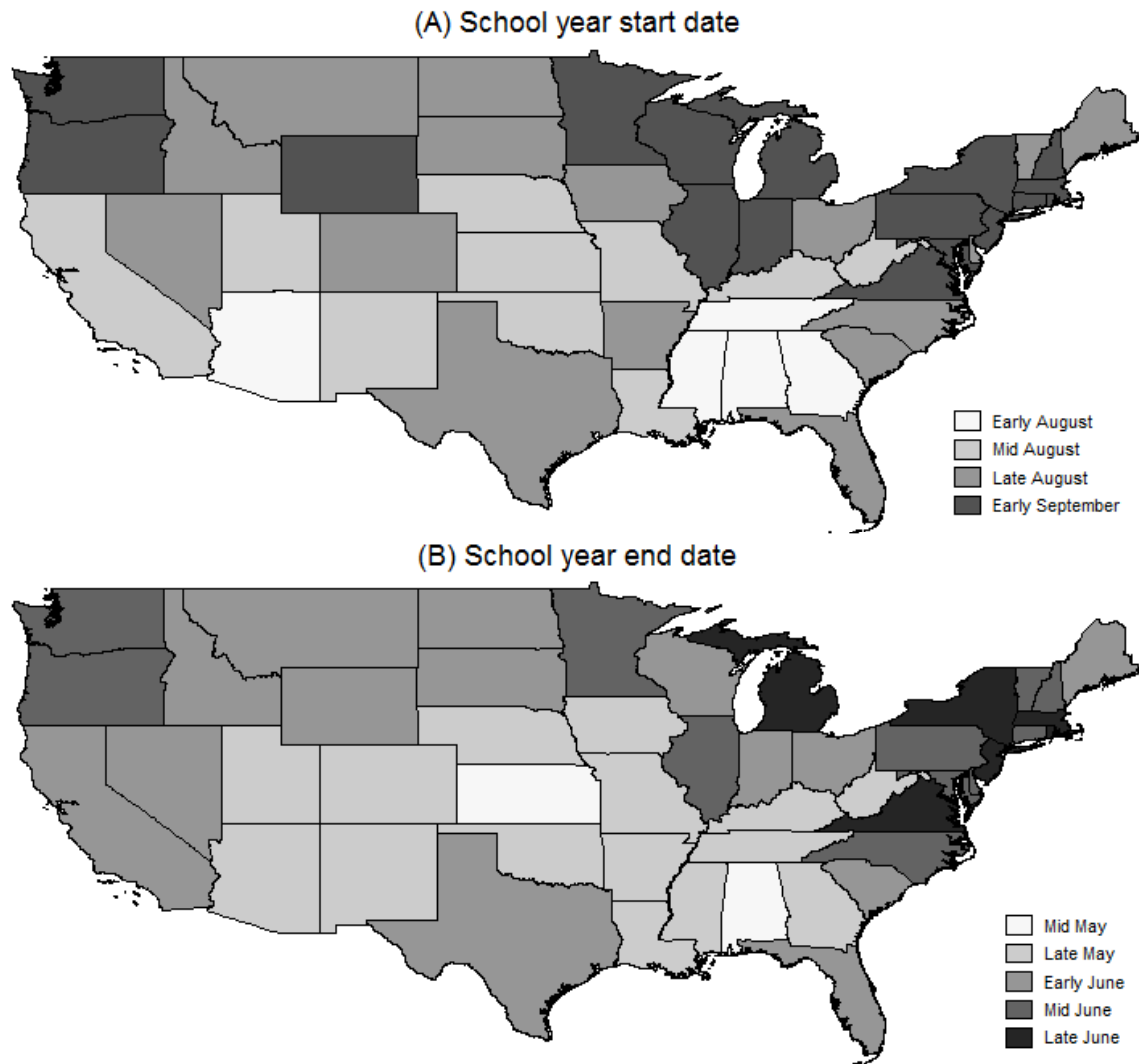


Online Appendix

Heat and Learning

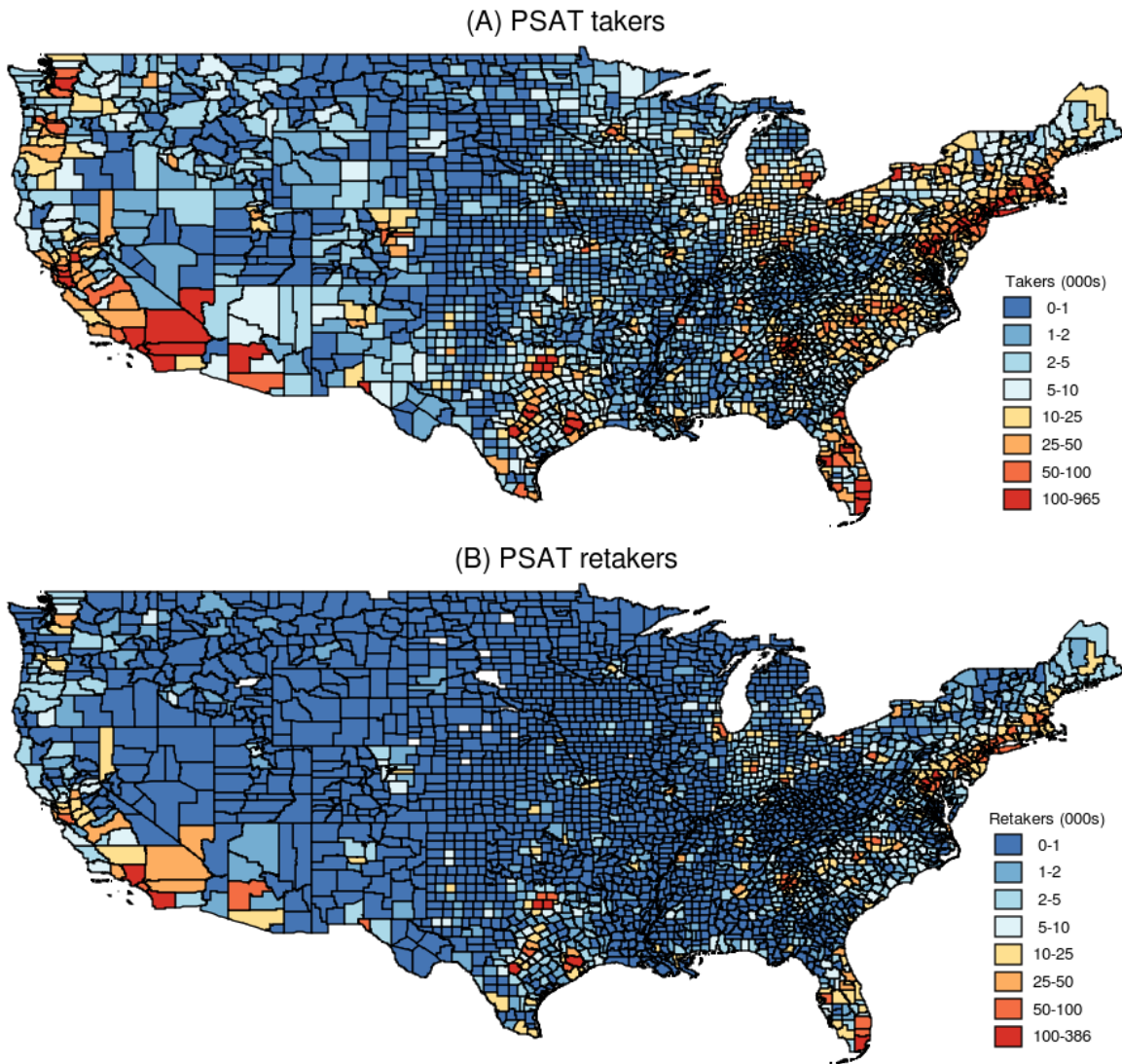
By R. Jinsung Park, Joshua Goodman, Michael Hurwitz, and Jonathan Smith

Figure A1. : School Year Calendars by State



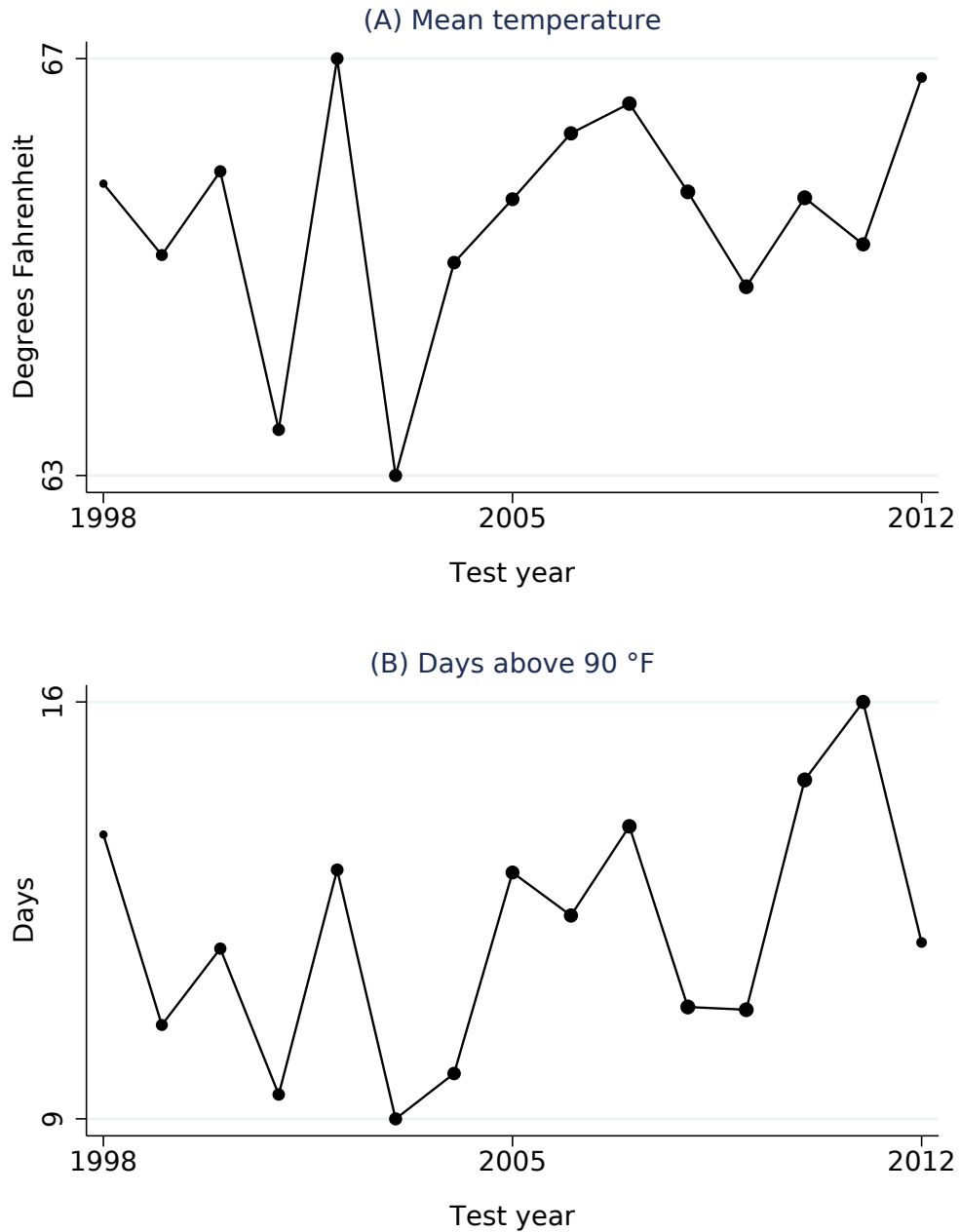
Notes: The above figure shows state's approximate school year start and end dates based on the largest school district in each state and as of 2016.

Figure A2. : Spatial Distribution of PSAT Takers



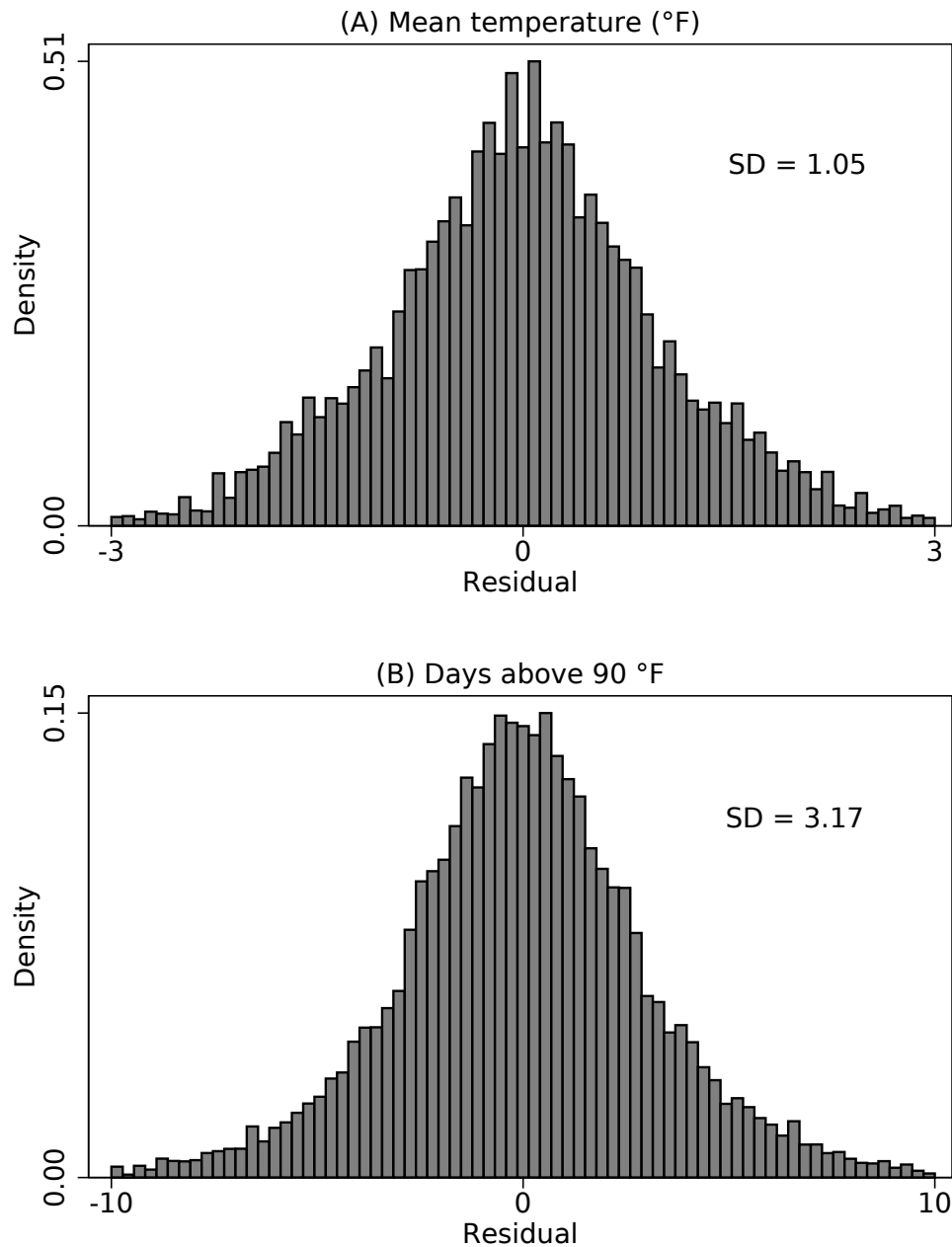
Notes: The above figure shows by county the total number of PSAT takers (panel A) and retakers (panel B) from the high school classes of 2001-14.

Figure A3. : Temporal Variation in Prior Year Temperature



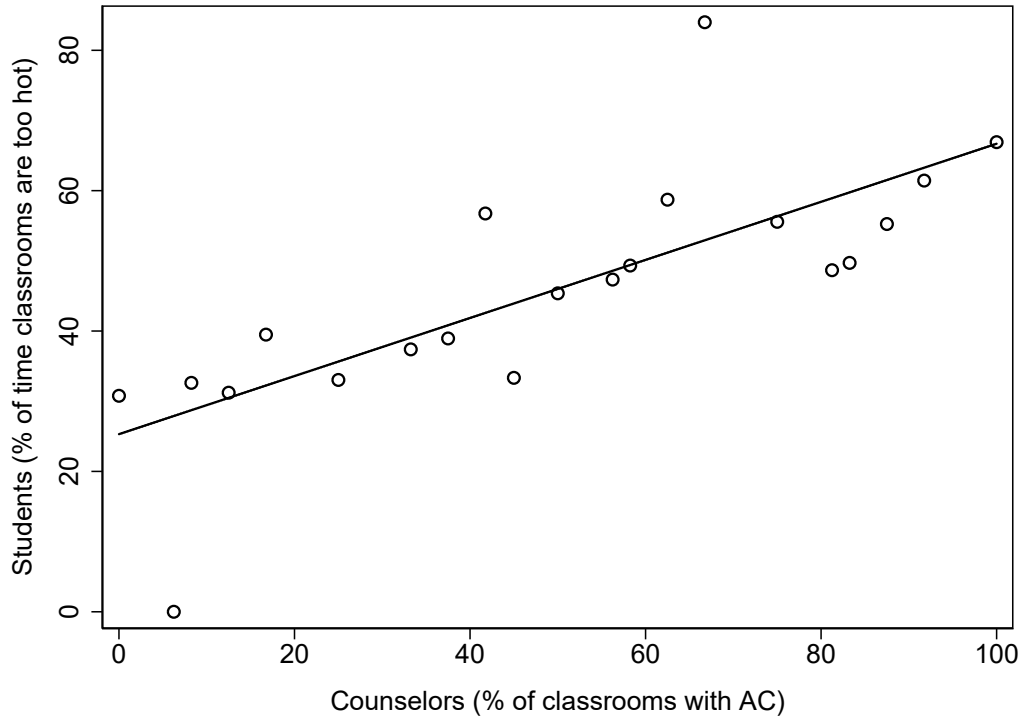
Notes: The above figure shows the mean daily maximum temperature (panel A) and number of days above 90°F (panel B) experienced by students on school days in the 365 days prior to taking the PSAT, by test year. The sample consists of all PSAT-takers from the high school classes of 2001-14, whose PSATs were taken between 1997 and 2012. Dot size is proportional to the number of students in each test year. Test year 1997 is excluded due to the small number of observations.

Figure A4. : Residuals of Prior Year Temperature



Notes: The above figure shows the distribution of residuals resulting from regressions on student fixed effects of the mean daily maximum temperature (panel A) and number of days above 90°F (panel B) experienced by students on school days in the 365 days prior to taking the PSAT. All regressions include fixed effects for each combination of cohort, test date and take number. The figure excludes residuals with magnitude above three (panel A) and 10 (panel B). The standard deviation of the full set of residuals is shown in each panel.

Figure A5. : Students and Counselors Reports of School Air Conditioning



Notes: The above figure shows a bin scatter comparing two measures of school air conditioning penetration rates. The vertical axis shows our preferred measure, constructed from student reports of the fraction of hot days on which classrooms are too hot for learning. The horizontal axis shows counselor reports of the fraction of classrooms with air conditioning. The sample includes all PSAT retakers for whom these two measures are non-missing. The correlation between the measures in this sample is 0.67.

Table A1—: Temperature and PSAT-Taking

	Takers (1)	Ln(takers) (2)	Female (3)	Black or Hispanic (4)	Mother has B.A. (5)	Father has B.A (6)
(A) Baseline						
Mean temperature (°F)	-0.0107 (0.0902)	-0.0021 (0.0017)	-0.0001 (0.0001)	0.0007*** (0.0002)	0.0003 (0.0003)	0.0003 (0.0003)
(B) State trends						
Mean temperature (°F)	-0.0924 (0.0812)	-0.0013 (0.0016)	0.0001 (0.0001)	0.0001 (0.0002)	-0.0001 (0.0002)	-0.0001 (0.0002)
N	686,977	686,977	27,021,552	27,021,552	27,021,552	27,021,552

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* $p < .10$ ** $p < .05$ *** $p < .01$). Each coefficient comes from a separate regression of the listed characteristic of PSAT-takers on the average daily maximum temperature from school days in the 365 days preceding a student's first PSAT take. All regressions include fixed effects for each high school and for each combination of cohort and test date. Panel B also includes state-specific linear time trends. The sample comprises all students from the high school classes of 2001-14 who took the PSAT at least once.

Table A2—: Temperature and Retaking

	(1)	(2)	(3)	(4)	(5)
Prior year temperature (°F)	0.0005 (0.0005)		0.0005 (0.0005)	0.0003 (0.0005)	-0.0001 (0.0004)
Following year temperature (°F)		0.0003 (0.0004)	0.0003 (0.0005)	0.0003 (0.0005)	-0.0004 (0.0004)
N	27,021,551	27,021,551	27,021,551	27,021,551	27,021,551
Test day temperature	No	No	No	Yes	Yes
State-specific time trends	No	No	No	No	Yes

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* $p < .10$ ** $p < .05$ *** $p < .01$). Each coefficient comes from a separate regression of the probability of retaking the PSAT on the weather measure(s) shown. Yearly temperatures are measured with the daily maximum temperature from school days in the 365 days preceding and following a student's first PSAT take. All regressions include fixed effects for each high school, for each combination of gender, race, income and parental education, and for each combination of cohort and test date. Columns 4 and 5 control for temperature on the day of the first PSAT take. Column 5 includes state-specific linear time trends. The sample comprises all students from the high school classes of 2001-14 who took the PSAT at least once.

Table A3—: Measurement Error from Sensor Distance

	All students (1)	Black or Hispanic (2)	White (3)	Low income (4)	High income (5)
Mean temp. (°F)	-0.237*** (0.045)	-0.389*** (0.061)	-0.085*** (0.025)	-0.279*** (0.050)	-0.091*** (0.032)
Sensor distance * Mean temp. (°F)	0.006** (0.003)	0.008* (0.004)	-0.001 (0.002)	0.006** (0.003)	-0.002 (0.002)
N	21,046,448	6,023,145	12,161,058	10,658,547	10,234,301

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* $p < .10$ ** $p < .05$ *** $p < .01$). Each coefficient comes from a separate regression of hundredths of a standard deviation in PSAT total (math plus reading) scores on the weather measure(s) shown. Each regression measures mean temperature using the daily maximum temperature from school days in the 365 days preceding the PSAT take. Also included is the interaction between temperature and distance from the nearest weather sensor (in miles). All regressions include student fixed effects and fixed effects for each combination of cohort, test date and take number. The sample in column 1 comprises all students from the high school classes of 2001-14 who took the PSAT more than once. Columns 4 and 5 contain students living in below and above median ZIP code-level income within below and above median temperature areas.

Table A4—: Temperature Effects by Test Subject

	Math (1)	Verbal (2)
<hr/>		
(A) Average heat		
Mean temperature (°F)	-0.159*** (0.034)	-0.177*** (0.023)
<hr/>		
(B) Hot days		
Days above 90 °F	-0.042*** (0.014)	-0.062*** (0.010)
N	21,046,448	21,046,448

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* $p < .10$ ** $p < .05$ *** $p < .01$). Coefficients in each column and panel come from a regression of hundredths of a standard deviation in PSAT math or reading scores on the weather measure shown. Panel A measures temperature with the daily maximum temperature from school days in the 365 days preceding the PSAT take. Panel B measures the number of such school days above 90 °F. All regressions include student fixed effects and fixed effects for each combination of cohort, test date and take number. Panel B also controls for the number of days in other temperature ranges, so that days in the 60s are the reference category. The sample comprises all students from the high school classes of 2001-14 who took the PSAT more than once.

Table A5—: Heterogeneity by Take Number

	(1)	(2)	(3)	(4)
Mean temp. (°F)		-0.152*** (0.034)	-0.200*** (0.027)	-0.269*** (0.069)
Mean temp. * 1st take	-0.152*** (0.034)		0.048** (0.021)	0.116 (0.079)
Mean temp. * 2nd take	-0.200*** (0.027)	-0.048** (0.021)		0.069 (0.065)
Mean temp. * 3rd take	-0.269*** (0.069)	-0.116 (0.079)	-0.069 (0.065)	
N	21,046,448	21,046,448	21,046,448	21,046,448

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* p<.10 ** p<.05 *** p<.01). Coefficients in each column and panel come from a regression of hundredths of a standard deviation in PSAT total (math plus reading) scores on interactions between take number and the average daily maximum temperature from school days in the 365 days preceding the PSAT take. All regressions include student fixed effects and fixed effects for each combination of cohort, test date and take number. The sample comprises all students from the high school classes of 2001-14 who took the PSAT more than once.

Table A6—: Future Temperature Shocks

	(1)	(2)	(3)	(4)	(5)
Mean temp., 1 year prior (°F)	-0.181*** (0.028)	-0.229*** (0.039)	-0.182*** (0.028)	-0.178*** (0.029)	-0.228*** (0.049)
Mean temp., 1 year after (°F)		-0.090* (0.048)			-0.092 (0.080)
Mean temp., 2 years after (°F)			0.053 (0.032)		-0.006 (0.073)
Mean temp., 3 years after (°F)				-0.037 (0.033)	-0.037 (0.051)
N	21,046,448	21,046,448	21,046,448	21,046,448	21,046,448

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* $p < .10$ ** $p < .05$ *** $p < .01$). Coefficients in each column and panel come from a regression of hundredths of a standard deviation in PSAT total (math plus reading) scores on the weather measure(s) shown. School day temperature is measured with the daily maximum temperature from school days in the listed 365 day period relative to the PSAT take. All regressions include student fixed effects and fixed effects for each combination of cohort, test date and take number. The sample comprises all students from the high school classes of 2001-14 who took the PSAT more than once.

Table A7—: Clustering by weather sensor versus state

	(1)	(2)
<hr/>		
(A) Average heat		
Mean temperature (°F)	-0.181*** (0.028)	-0.181*** (0.041)
<hr/>		
(B) Hot days		
Days above 100 °F	-0.067*** (0.018)	-0.067*** (0.014)
Days in 90s (°F)	-0.053*** (0.013)	-0.053*** (0.020)
Days in 80s (°F)	-0.035*** (0.009)	-0.035** (0.014)
Days in 70s (°F)	-0.024*** (0.008)	-0.024* (0.015)
Days below 60 °F	0.010 (0.009)	0.010 (0.014)
N	21,046,448	21,046,448
Clustering by	Weather sensor	State

Notes: Heteroskedasticity robust standard errors clustered by weather sensor (column 1) or state (column 2) are in parentheses (* p<.10 ** p<.05 *** p<.01). Coefficients in each column and panel come from a regression of hundredths of a standard deviation in PSAT total (math plus reading) scores on the weather measure(s) shown. Temperature is measured with the daily maximum temperature from school days in the 365 days preceding the PSAT take. All regressions include student fixed effects and fixed effects for each combination of cohort, test date and take number. The sample comprises all students from the high school classes of 2001-14 who took the PSAT more than once.

Table A8—: Heterogeneity in Prior Year Temperature Impacts by Humidity

	Humid areas (1)	Arid areas (2)
Mean temperature (°F)	-0.186*** (0.038)	-0.111*** (0.028)
Days above 90 °F	-0.068*** (0.014)	-0.035** (0.015)
N	14,492,113	6,435,636

Notes: Heteroskedasticity robust standard errors clustered by weather sensor are in parentheses (* $p < .10$ ** $p < .05$ *** $p < .01$). Each coefficient comes from a separate regression of hundredths of a standard deviation in PSAT total (math plus reading) scores on the weather measure(s) shown. The first row measures mean temperature using the daily maximum temperature from school days in the 365 days preceding the PSAT take. The second row measures the number of such school days above 90 °F and controls for the number of days in other temperature ranges, so that days in the 60s are the reference category. All regressions include student fixed effects and fixed effects for each combination of cohort, test date and take number. The sample comprises all students from the high school classes of 2001-14 who took the PSAT more than once. Columns 1 and 2 contain students living in areas with below and above the median of the US summer humidity distribution, as characterized by ZIP code level summer dewpoints.