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The heat: temperature, police behavior and the enforcement of law

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Abstract
Despite ample investigation into the influence of ambient temperature on behavior, and especially on criminal activity, little research exists on the impact of temperature on police behavior. As such, this analysis tests the "heat hypothesis" over 5 years of traffic stops by the City of Pittsburgh Police Department. Across a range of specifications, police officers are more likely to issue traffic citations when temperatures are warmer—holding constant driving behavior—and the magnitude of the increase is comparable to citation rate discrepancies between black and white drivers.

Keywords Heat hypothesis · Traffic stops · Enforcement of law

JEL Classification K42

1 Introduction

Weather influences mood, and mood impacts behavior. Sunlight shapes investment decisions (Levy and Galili 2008), higher temperatures make for more aggressive athletes (Reifman et al. 1991; Craig et al. 2016), and good weather decreases worker productivity (Lee et al. 2014). While an extensive literature exists exploring the relationship between, and psychological channels connecting, ambient temperature and human behavior, of particular interest to this study is the heat hypothesis and the heat effect. Anderson (2001) explains that

> [t]he *heat hypothesis* states that hot temperatures increase aggressive motivation and (under some conditions) aggressive behavior. The *heat effect* is the observation of higher rates of aggression by people who are hot relative to people who are cooler.

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As the heat hypothesis and the heat effect deal with aggression and aggressive behavior, criminal behavior has emerged as a natural venue for testing. Cohn (1993) finds that domestic violence is more prevalent as temperatures increase; a similar relationship exists concerning property crimes (see, for example, Cohn and Rotton 2000). Homicides increase with temperatures (see, for example, Cheatwood 1995; Hagelin et al. 1999; Ikegaya and Suganami 2008), as do assaults (see, for example, Harries et al. 1984; Hagelin et al. 1999; McDowall and Curtis 2015).

Despite the exploration of the interaction between temperature and the violation of the law, this study is the first to the author's knowledge to examine the relationship between temperature and the *enforcement* of the law. In brief, police officers are more likely to issue traffic citations when temperatures are warmer—holding constant driving behavior—and the magnitude of the increase is comparable to citation rate discrepancies between races.

2 Background

2.1 Literature review

Issuing a traffic citation is one of several discretionary actions performed by police officers; as such, many studies have looked to isolate the determinants of discretionary police behavior. Stop-and-frisk programs have received ample research attention, with most studies finding distortions in program implementation along race lines; see, for example, Ridgeway (2007), Gelman et al. (2007) and Fryer (2016). Frisking specifically during traffic stops also has been explored, with similar race-based conclusions; see, for example, Carroll and Gonzalez (2014) and Ryan (2016). Searching a stopped vehicle is another discretionary act made along race lines; see, for example, Rojek et al. (2004), Rosenfeld et al. (2012), and Novak and Chamlin (2012). The decision to initiate a traffic stop is itself discretionary and could plausibly be a function of race as well; see, for example, Grogger and Ridgeway (2006), Ritter (2013) and Horrace and Rohlin (2016). While race has received a substantial amount of attention in the extant literature, other factors, such as officer/civilian gender, third party individuals such as passengers or bystanders, location and time of day have been considered as well.

Particular to this study, officers' decisions to issue citations have numerous influences. As above, race plays a role in whether to cite a driver during a traffic stop; see, for example, Warren et al. (2006), Moon and Corley (2007), and Anbarci and Lee (2014). Both driver and officer gender impact citation likelihood; see, for example, Lundman and Kaufman (2003) and Farrell (2015). Age can influence the citation decision as well; see, for example, Lundman and Kaufman (2003), Miller (2009) and Rosenfeld et al. (2012). The fiscal health of local governments can help explain citation patterns and amounts; see Garrett and Wagner (2009) and Makowsky and Stratmann (2009). Out-of-area drivers appear to be discriminated against; see Makowsky and Stratmann (2009) and Rowe (2010). Hummel (2015) highlights a focus on public safety over budget concerns when issuing citations. Day and Ross

(2011) find that remorseful drivers received lower fines for speeding. The influence of temperature on citation-issuing behavior, however, has yet to be explored.

Exploration into the impact of ambient temperature on human behavior spans millennia. Ancient Roman orator Cicero famously noted that "the minds of men do in the weather share." Iyigun et al. (2017) find that global cooling from 1400 to 1900 was associated with an increase in conflict. More recently, psychologists have identified that heat generates discomfort in the mind and body, and that this discomfort activates the human fight-or-flight response which, in turn, manifests itself as aggression; for additional psychological and biological analyses, see, for example, Anderson (1989), Berkowitz (1993) and Anderson (2001), amongst a very extensive literature. Many empirical analyses have focused on this aggression emerging as criminal activity. Cities in warmer climates appear to have higher violent crime rates; see Field (1992) and Anderson et al. (2000). Moreover, several specific types of crime related to aggression also appear to be correlated with higher temperatures; please see Sect. 1.

To the knowledge of the author, only one existing study has examined the direct influence of temperature upon police behavior, as compared to the indirect influence of police response to criminal activity. Vrij et al. (1994) found officers more likely to draw and fire their weapon in hot conditions during a field experiment in Holland. While the consequences of the decision by an officer to draw, or fire, their weapon may be more severe than the decision to issue a citation, there nevertheless exists evidence to indicate that ambient temperature has an influence on police officer behavior. Further, insofar that temperature impacts a reactionary decision like drawing or firing a weapon, it is plausible that it may also influence—perhaps to a larger degree—a more measured decision such as the choice to issue a citation during a traffic stop.

2.2 Data

To determine the impact of temperature on officer behavior, a dataset of 136,559 individual traffic stops are utilized from the City of Pittsburgh Police Department.[1] These data constitute the universe of traffic stops performed by the City of Pittsburgh Police Department from January 1, 2011 through December 31, 2015. Each traffic stop has four possible outcomes: investigatory stop, warning, citation, and arrest. The following control variables derive directly from each traffic stop: The date and time of the traffic stop, the gender of the driver (***Male***), whether there were additional passengers in the vehicle (***Solo***), the race of the driver (***White***, ***Black***, ***Other***), the shift in which the stop took place (***Shift 1***, ***Shift 2***, ***Shift 3***),[2] whether the stop took place during the weekend (***Weekend***), and the location of the traffic stop

[1] The city of Pittsburgh spans approximately 60 square miles, and the population of the metro area exceeds 2 million.

[2] Shift 1 denotes stops performed from 7:00 am to 3:00 pm, Shift 2 denotes stops performed from 3:00 pm to 11:00 pm, and Shift 3 denotes stops performed from 11:00 pm to 7:00 am.

(***Zone 1*** through ***Zone 7***). In 118 stops (0.09% of all stops), the gender of the driver was not recorded; these stops are excluded from all analyses utilizing ***Male***.

Temperature data come from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. A wide range of atmospheric data are recorded hourly; for the purposes of this study, I incorporate two temperature variables: Temperature, in degrees Fahrenheit (***Temp***), and heat index (***Heat Index***), a figure calculated by NOAA from ambient temperature in degrees Fahrenheit and relative humidity.[3] As humidity is often understood to increase discomfort at higher temperatures, the possibility exists that a simple Fahrenheit temperature might not capture the full nature of the ambient atmospheric conditions. However, as the two measures are very highly correlated (r = 0.9988), the specific form of our temperature variable does not impact our results in any substantive manner. Each traffic stop is matched with the recorded temperature and heat index during the hour of the traffic stop. Table 1 provides summary statistics for the data.

A number of modest assumptions must be made with regards to the temperature data and its application to each individual traffic stop. NOAA collects hourly weather data at Pittsburgh International Airport, which, while located approximately 20 miles from downtown Pittsburgh, is the closest available hourly weather data available from NOAA. The author has no reason to believe that these weather readings are not an exceedingly effective proxy for the weather during each individual traffic stop. Further, insofar that these data may not represent the "true" weather in Pittsburgh, the author has no reason to believe that these readings are systematically biasing the results herein. These data assume a constant, within-hour temperature and heat index throughout the geography of Pittsburgh. While certain

Table 1 Summary statistics

	N	μ	σ	Min.	Max.
Heat Index	136,559	52.46	21.36	− 17.62	104.86
Temp	136,559	54.20	19.38	− 9	97
Diff Temp.	136,559	− 7.46	10.86	− 52	31
Male	136,441	0.68	0.47	0	1
Race = ***Black***	136,559	0.36	0.48	0	1
Race = ***White***	136,559	0.58	0.49	0	1
Race = ***Other***	136,559	0.06	0.24	0	1
Shift 1	136,559	0.36	0.48	0	1
Shift 2	136,559	0.43	0.49	0	1
Shift 3	136,559	0.22	0.41	0	1
Weekend	136,559	0.21	0.41	0	1
Solo	136,559	0.64	0.48	0	1

[3] NOAA provides the following equation for the generation of heat index (HI) from temperature (T) and relative humidity (RH):

HI = − 42.379 + 2.04901523*T + 10.14333127*RH − .22475541*T*RH − .00683783*T*T − .05481717*RH*RH + .00122874*T*T*RH + .00085282*T*RH*RH − .00000199*T*T*RH*RH.

micro-climates may exist throughout the city, the author again feels no reason to believe that the results herein to be biased. Nevertheless, to the degree that micro-climates may influence the results, zone-specific fixed effects help mitigate this particular possibility as well. Finally, every traffic stop is matched with an hourly temperature value. As NOAA temperature values at the Pittsburgh International Airport are collected at 51 min past every hour, the maximum amount of time between a temperature reading and a traffic stop is 51 min. Temperatures could change over this time frame, and the results would be accordingly biased. However, as temperatures increase and decrease, there is little reason to believe that there is an a priori direction to the conceivable bias. Insofar that temperatures increase (decrease) more frequently during the daytime (nighttime), controlling for the shift in which the stop occurred helps mitigate these effects. In any case, the mean change in temperature within the dataset from hour to hour—that is, the mean of the absolute value of all hourly changes over the 5 years covered in these data—is 1.41 degrees Fahrenheit; for heat index, the mean change is 1.46 degrees Fahrenheit. In theory, and in practice, it is difficult to imagine the hourly weather constraint as a palpable driver of the results presented in this analysis.

Finally, the particular nature of a traffic stop provides a unique opportunity for weather to condition only one side of a social interaction. While not without exception, civilians and police officers operate motor vehicles largely within the climate-controlled environment of a vehicle.[4] A traffic stop, by nature, necessitates that one side of the encounter—the police officer—becomes subject to the ambient weather conditions prior to their discretionary action of issuing (or not issuing) a citation, while the other—the civilian—remains in a climate-controlled environment. As such, traffic stops appear remarkably well-suited to test the heat hypothesis.

2.3 Weather, driving and aggression

As this study is examining the emergence of aggression in the form of an increased likelihood to issue a citation to a stopped driver, the incidence of aggressive driving behavior as it pertains to the ambient temperature is of interest. There are two issues at hand. First, to what degree does temperature impact driving behavior? And second, to what degree could this driving behavior influence the analysis of officer behavior?[5]

To address the first issue, a direct measure of driver aggression across all drivers would be ideal. Then, after controlling for the appropriate factors, the impact of temperature upon driving behavior could be isolated. Complete data on all driving *trips*, however, are simply not available; instead, what exists is information on every traffic *stop*. The appropriate benchmark by which to compare these traffic stops, therefore,

[4] Interestingly, Kenrick and MacFarlane (1986) found that spring and summertime drivers in Phoenix are more likely to honk their horns as temperatures rise, and even moreso should their windows be open.

[5] Do note that the aggression measured in this analysis is solely the officer's. The data are unable to capture any aggression by the driver during the traffic stop itself, and thus unable to discern any role that may play in the discretionary behavior of the officer.

becomes a crucial issue; for a full discussion concerning benchmarking in police data, see Ridgeway (2007).

To provide an appropriate benchmark, the following null hypothesis is tested: Should driving behavior be unaffected by temperature, then the proportion of traffic stops at a given temperature should be equal to the proportion of hours at that same temperature. Rejecting this null hypothesis points to temperature impacting driving behavior.

Table 2 presents the results of this test. Temperatures are grouped every five degrees. Then, two proportions are generated within these temperature groups: (1) the proportion of total traffic stops that occurred while the temperature was within the pertinent range, and (2) the proportion of hours throughout the dataset that had temperatures within the pertinent range. Z-scores for a two-sample test of proportions between the proportion pairs are reported, with positive (negative) z-scores indicating a higher (lower) proportion of traffic stops occurring than would be expected given the proportion of hours within the pertinent temperature range. The results show that traffic stops occur more (less) frequently at warmer (cooler) temperatures relative to the number of hours at said temperatures. Note, however, the specific driving behavior that is correlated with temperature. For all temperature

Table 2 Traffic stops and temperature

Temp. range	% of total stops	% of total hours	Z-score
95 to 100	0.02	0.02	0.1801
90 to 95	0.22	0.16	**2.6181****
85 to 90	1.78	1.13	**9.9306*****
80 to 85	4.92	3.26	**15.4914*****
75 to 80	7.84	5.74	**15.6619*****
70 to 75	9.87	8.99	**5.7674*****
65 to 70	9.78	10.07	**−1.9098***
60 to 65	9.11	9.37	**−1.7245***
55 to 60	8.08	8.14	−0.4225
50 to 55	6.99	7.78	**−5.8714*****
45 to 50	6.13	6.60	**−3.7984*****
40 to 45	7.08	7.22	−1.0508
35 to 40	7.00	7.15	−1.1533
30 to 35	7.83	8.31	**−3.4287*****
25 to 30	5.85	6.69	**−6.7449*****
20 to 25	3.41	3.86	**−4.7215*****
15 to 20	2.15	2.81	**−8.4891*****
10 to 15	0.97	1.24	**−5.2756*****
5 to 10	0.58	0.77	**−4.6965*****
0 to 5	0.33	0.48	**−4.6617*****
−5 to 0	0.05	0.13	**−5.8711*****
−10 to −5	0.01	0.06	**−6.2634*****

***, **, *Statistical significance at the 99% (95%, 90%) level for a two-sample proportion test. Z-scores with associated statistical significance greater than 90% are in bold ranges in which a statistically greater number of traffic stops occurred above the corresponding percentage of total hours at those temperatures—from 70 degrees Fahrenheit to 95 degrees Fahrenheit—over 93% of the traffic stops performed take place during Shift 1 and Shift 2. By comparison, only 74% of traffic stops take place during Shift 1 and Shift 2 at a temperature under 70 degrees Fahrenheit. Of course, warmer temperatures occur more frequently during the daytime hours—when more individuals are driving. As such, more traffic stops are taking place during these temperature ranges simply because there are more people driving.[6]

To address the second issue—whether the results herein are a function of more aggressive driving at higher temperatures–it is worth considering the particular nature of the traffic stop data. Note again that the increase in the propensity of an officer to issue a traffic citation is during a traffic stop, not a driving trip. As such, any behavior exhibited by the driver prior to the stop is largely filtered out of these data. By looking at traffic stops, officer behavior is analyzed *after* any behavior that driver exhibited to warrant the traffic stop. Any additional aggressive driving behavior due to an increase in temperature is therefore not borne out in the increased likelihood of an officer to issue a citation.

In fact, rough evidence exists that points precisely to the increasing propensity of officers to issue citations as temperatures rise. Table 3 presents the percentage of traffic stops that result in a citation by temperature. For those temperatures above 70 degrees Fahrenheit, the percentage of traffic stops that result in a citation surpasses 51%. For those temperatures below 70 degrees Fahrenheit, the rate drops to 45%.

One final consideration is the possibility that the shift length—8 h—is a binding constraint on the number of traffic stops that officers can perform. As such, the more-aggressive driving due to increased temperatures influences officer behavior in such a way that only particularly severe driving infractions are stopped, and therefore an increase in the citation rate results. The traffic stop data and City of Pittsburgh Police Department characteristics, however, rule out this possibility. Shift 2 contains the largest incidence of traffic stops—58,225—in the dataset; at 1826 individual Shift 2 s from 2011 through 2015, this yields approximately 32 stops per shift, or 4 per hour. The City of Pittsburgh Police Department reports an average of 76 officers on patrol during any given shift. While all officers are not tasked solely with enforcing traffic laws—and indeed, shouldn't be—there appears to be a sufficient level of slack such that the shift length is not a binding constraint. Aggressive driving behavior can reasonably be expected to result in a traffic stop, or probability of a traffic stop, equally across all temperatures and all times of day.

[6] Further, the demographic breakdown across temperatures warrants a brief note. While gender remains roughly constant across all temperatures, the proportion of black drivers falls as temperatures rise. Insofar that black drivers are more likely to receive citations as compared to white drivers, the measurement of police aggression due to temperature increases may be biased downwards.

Table 3 Citation percentage, time of day and temperature

Temp. range	(3) Citation percentage	Shift 1%	Shift 2%	Shift 3%
95 to 100	51.61	16.13	83.87	0.00
90 to 95	58.25	56.90	43.10	0.00
85 to 90	52.25	43.47	56.24	0.29
80 to 85	55.31	44.84	54.76	0.40
75 to 80	52.78	42.03	53.50	4.47
70 to 75	50.75	41.22	45.64	13.14
65 to 70	48.80	36.98	39.79	23.23
60 to 65	47.41	35.13	37.38	27.49
55 to 60	43.70	31.55	39.42	29.03
50 to 55	45.43	31.96	40.61	27.43
45 to 50	45.19	34.15	41.39	24.47
40 to 45	46.70	34.33	44.29	21.38
35 to 40	46.35	33.64	41.87	24.49
30 to 35	45.06	34.21	40.86	24.93
25 to 30	43.80	27.82	39.36	32.82
20 to 25	43.39	33.67	39.06	27.27
15 to 20	43.13	33.42	32.23	34.34
10 to 15	38.09	30.88	40.21	28.91
5 to 10	37.36	24.53	35.97	39.50
0 to 5	34.81	18.85	20.62	60.53
−5 to 0	42.86	17.14	28.57	54.29
−10 to −5	25.00	12.50	0.00	87.50

3 Empirical analysis

3.1 Model

To explore the impact of temperature upon the likelihood that an officer issues a citation during a traffic stop, a traditional probit model is utilized for all specifications. The underlying latent variable, f_i^* for each traffic stop i, is a function of a vector of observed characteristics x_i, with unknown weights β and a random error term ε_i. This relationship is as follows:

$$f_i^* = \mathrm{x}_\mathrm{i}'\beta + \varepsilon_\mathrm{i}$$

where under the assumption of normality, the probability that the driver receives a traffic citation is

$$\Pr(f_i = 1|\mathrm{x}_i) = \Pr(f_i^* > 0|\mathrm{x}_i) = \varphi(\mathrm{x}_\mathrm{i}'\beta)$$

and, correspondingly, does not receive a traffic citation

$$\Pr(f_i = 0|\mathrm{x}_i) = \Pr(f_i^* \le 0|\mathrm{x}_i) = 1 - \varphi(\mathrm{x}_\mathrm{i}'\beta)$$

where φ (·) represents the standard normal cumulative distribution function.

3.2 Results and discussion

Table 4 presents the main results; all reported estimates are marginal effects and are statistically significant to the 99% level. In addition, all Chi-squared values in these and subsequent regressions easily reject at the 99% level of statistical significance that these results are due to chance. All regressions include fixed effects for the year in which the traffic stop takes place should broad, annual discrepancies in traffic enforcement exist. The primary specifications in this analysis exclude stops ending in arrest. As arrests may take place for reasons beyond the scope of the traffic stop—for example, an outstanding warrant—these stops may bias upwards the "true" rate of citation should arrests be counted as a stop ending in a citation. There

Table 4 Probit analysis of traffic stops, main results

	Dependent variable: did the driver receive a citation during the traffic stop? (1 = yes)			
	(1)	(2)	(3)	(4)
	Year	Year, zone	Year	Year, zone
Fixed effects				
Heat Index	**0.0016***** **(0.0001)**	**0.0009***** **(0.0001)**		
Temp			**0.0019***** **(0.0001)**	**0.0011***** **(0.0001)**
Male		**− 0.0277***** **(0.0030)**		**− 0.0277***** **(0.0030)**
Race = ***Black***		**0.0146***** **(0.0032)**		**0.0146***** **(0.0032)**
Race = ***Other***		**0.0447***** **(0.0060)**		**0.0447***** **(0.0060)**
Shift 1		**0.2231***** **(0.0040)**		**0.2223***** **(0.0040)**
Shift 2		**0.1071***** **(0.0039)**		**0.1062***** **(0.0039)**
Weekend		**− 0.0589***** **(0.0035)**		**− 0.0589***** **(0.0035)**
Solo		**0.0377***** **(0.0030)**		**0.0376***** **(0.0030)**
N	130,789	130,672	130,789	130,672
Chi-Sq	2117.3	8751.8	2163.4	8763.0

Marginal effects reported. Robust standard errors in parenthesis. A constant term is included in each specification

***Statistical significance at the 99% level. All estimates exceeding a statistical significance of 99% are in bold are 5770 arrests during traffic stops in the data, constituting 4.23% of all traffic stop outcomes; nevertheless, specifications utilizing stops ending in arrest are explored below and are not substantively different from the main specifications. Regression 1 includes only the heat index as an independent variable. A one-standard deviation increase in the heat index increases the probability of receiving a traffic citation by approximately 3.4 percentage points. Regression 2 includes a full set of available control variables, adding additional fixed effects for the zone in which the stop occurred. While not the focus of this analysis, the additional control variables have signs and magnitudes in accordance with previous research; please refer to the literature review for additional discussion and citations. Male drivers are cited less frequently than female drivers, likely due to a disproportionate number of investigatory stops performed on male drivers. Both black drivers and non-black, non-white drivers are cited at higher rates as compared to white drivers, at approximately 1.5 and 4.5 percentage points, respectively.[7] Citations rates are far higher during Shifts 1 and 2 as compared to Shift 3, again likely due to the preponderance of investigatory stops taking place during night hours. Weekend stops are less likely to result in citation and drivers without passengers are more likely to be cited. The inclusion of the control variables reduces the size of the estimate for heat index; a one-standard deviation increase in the heat index now increases the likelihood of receiving a citation by approximately 1.9 percentage points. Still, this impact is comparable to—indeed, larger than—the discrepancy in citation likelihood between black and white drivers. Regressions 3 and 4 mirror Regressions 1 and 2, using temperature in place of heat index. A one-standard deviation increase in the ambient temperature increases the likelihood of citation by approximately 3.7 percentage points (Regression 3) and approximately 2.1 percentage points (Regression 4). The control variables remain nearly identical between Regressions 2 and 4. The main regression results clearly show evidence for the heat hypothesis: higher temperatures increase the likelihood that a stopped driver receive a citation.

Table 5 tests the sensitivity of the main results to the decision to exclude traffic stops ending in arrest from the analysis. The results are effectively unchanged and statistical significance of 99% remains across all estimates. The one-standard deviation increase in heat index leads to an approximately 3.0 percentage point increase in citation likelihood (Regression 5); with a full slate of control variables, the increase is 1.7 percentage points (Regression 6). Using temperature as the variable of interest, the one-standard deviation increase is 3.1 percentage points (Regression 7) and 1.7 percentage points (Regression 8). The control variables remain consistent in sign, though some mild changes in magnitude occur; ***Male***, ***Black*** and ***Weekend*** increase with the inclusion of arrests while ***Other***, ***Shift 1***, ***Shift 2***, and ***Solo*** decrease. That officers are more likely to issue citations in higher temperatures is not a function of excluding arrests from the main specifications.

Table 6 focuses the analysis on traffic stops that occur at or above the mean heat index/temperature values. While Tables 3 and 4 provide estimates across all traffic

[7] For further exploration of the roles of race and gender during traffic stops, please see Lundman and Kaufman (2003) and Ryan (2016), amongst many.

Table 5 Probit analysis of traffic stops, with arrests

	Dependent variable: did the driver receive a citation/arrest during the traffic stop? (1 = yes)			
	(5)	(6)	(7)	(8)
	Year	Year, zone	Year	Year, zone
Fixed effects				
Heat Index	**0.0014***** **(0.0001)**	**0.0008***** **(0.0001)**		
Temp			**0.0016***** **(0.0001)**	**0.0009***** **(0.0001)**
Male		**−0.0118***** **(0.0029)**		**−0.0118***** **(0.0029)**
Race = ***Black***		**0.0249***** **(0.0031)**		**0.0249***** **(0.0031)**
Race = ***Other***		**0.0311***** **(0.0059)**		**0.0311***** **(0.0059)**
Shift 1		**0.1800***** **(0.0039)**		**0.1793***** **(0.0039)**
Shift 2		**0.0858***** **(0.0037)**		**0.0850***** **(0.0037)**
Weekend		**−0.0542***** **(0.0035)**		**−0.0542***** **(0.0035)**
Solo		**0.0280***** **(0.0029)**		**0.0280***** **(0.0029)**
N	136,559	136,441	136,559	136,441
Chi-Sq	1834.5	7185.0	1871.5	7194.5

Marginal effects reported. Robust standard errors in parenthesis. A constant term is included in each specification

***Statistical significance at the 99% level. All estimates exceeding a statistical significance of 99% are in bold

stops—and therefore, all temperature ranges—it may be prudent to consider the impact of increases in temperature only amongst temperatures broadly considered to be warm. Possibly, the effect of moving from cold to cool may be different than the effect of moving from warm to hot. Regressions 9 through 12 mirror Regressions 1 through 4 applied to any traffic stop, excluding arrests, with a heat index equal to or greater than 52.46 (Regressions 9 and 10), or a temperature equal to or greater than 54.20 degrees Fahrenheit (Regressions 11 and 12). Two results are worth noting. First, while the marginal effects increase, the standard deviation of heat index/temperature also decreases within the subsample. As such, a one-standard deviation change in heat index ($\sigma_{\textbf{\textit{Heat Index}} > \mu} = 9.89$) has a similar overall magnitude as the main results—approximately 3.4 percentage points (Regression 9) and approximately 1.5 percentage points (Regression 10)—and the same holds true for a one-standard deviation change in temperature ($\sigma_{\textbf{\textit{Temp}} > \mu} = 8.78$), at approximately 3.6 percentage points (Regression 11) and approximately 1.7 percentage points (Regression 12). Still, a one degree increase has approximately double the marginal effect

Table 6 Probit analysis of traffic stops, warmer temperatures

	Dependent variable: did the driver receive a citation during the traffic stop? (1 = yes)			
	(9)	(10)	(11)	(12)
Fixed effects	Year	Year, zone	Year	Year, zone
Heat Index	**0.0034***** **(0.0002)**	**0.0015***** **(0.0002)**		
Temp			**0.0041***** **(0.0002)**	**0.0019***** **(0.0002)**
Male		**−0.0358***** **(0.0041)**		**−0.0364***** **(0.0041)**
Race = ***Black***		0.0013 (0.0044)		−0.0003 (0.0044)
Race = ***Other***		**0.0368***** **(0.0082)**		**0.0377***** **(0.0082)**
Shift 1		**0.2193***** **(0.0059)**		**0.2162***** **(0.0060)**
Shift 2		**0.1388***** **(0.0059)**		**0.1351***** **(0.0060)**
Weekend		**−0.0673***** **(0.0051)**		**−0.0672***** **(0.0051)**
Solo		**0.0505***** **(0.0042)**		**0.0509***** **(0.0042)**
N	69,924	69,870	69,449	69,395
Chi-Sq	1094.71	4885.5	1121.0	4838.1

Marginal effects reported. Robust standard errors in parenthesis. A constant term is included in each specification

All models analyze traffic stops occurring only when ***Heat Index/Temp*** is greater than the respective mean value

***Statistical significance at the 99% level. All estimates exceeding a statistical significance of 99% are in bold

amongst warmer temperatures as compared to the entire temperature spectrum. In any case, increasing temperatures increase the likelihood of issuing a traffic citation.

Second, ***Black*** becomes statistically insignificant when included in Regression 10 and 12. More directly, the discrepancy in citation likelihood between blacks and whites disappears at warmer temperatures, though a gap still exists between non-black, non-white drivers and white drivers. The author offers no explanation for this peculiar outcome and welcomes future research into the matter. Interestingly, Cohen and Krueger (2016) find that surveys administered at warmer temperatures skew responses against policies favoring racial minorities. Insofar that survey responses can be compared to discretionary police behavior, these results would imply the opposite—a movement towards unbiased discretionary behavior across races. All

Table 7 Probit analysis of traffic stops, temperature differences

	Dependent variable: did the driver receive a citation during the traffic stop? (1 = yes)					
	(13)	(14)	(15)	(16)	(17)	(18)
Fixed effects	Year	Year, zone	Year	Year, zone	Year	Year, zone
Temp	**0.0019***** **(0.0001)**	**0.0011***** **(0.0001)**			**0.0014***** **(0.0001)**	**0.0011***** **(0.0001)**
Temp Diff			**0.0029***** **(0.0001)**	**0.0010***** **(0.0001)**	**0.0016***** **(0.0002)**	−0.0001 (0.0002)
Male		**−0.0277***** **(0.0030)**		**−0.0276***** **(0.0030)**		**−0.0277***** **(0.0030)**
Race = ***Black***		**0.0146***** **(0.0032)**		**0.0141***** **(0.0032)**		**0.0146***** **(0.0032)**
Race = ***Other***		**0.0447***** **(0.0060)**		**0.0449***** **(0.0060)**		**0.0447***** **(0.0060)**
Shift 1		**0.2223***** **(0.0040)**		**0.2233***** **(0.0041)**		**0.2227***** **(0.0041)**
Shift 2		**0.1062***** **(0.0039)**		**0.1065***** **(0.0040)**		**0.1066***** **(0.0041)**
Weekend		**−0.0589***** **(0.0035)**		**−0.0603***** **(0.0035)**		**−0.0589***** **(0.0035)**
Solo		**0.0376***** **(0.0030)**		**0.0375***** **(0.0030)**		**0.0377***** **(0.0030)**
N	130,789	130,672	130,789	130,672	130,789	130,672
Chi-Sq	2163.4	8763.0	2009.1	8631.4	2254.4	8763.6

Marginal effects reported. Robust standard errors in parenthesis. A constant term is included in each specification

***Statistical significance at the 99% level. All estimates exceeding a statistical significance of 99% are in bold

remaining variables are statistically significant to the 99% level and maintain their sign with a modicum of movement from the main specifications.

Table 7 explores the possibility of not only temperature impacting the likelihood of an officer issuing a citation during a traffic stop, but temperature relative to an expected temperature. NOAA provides monthly average high temperatures for Pittsburgh, and ***Temp Diff*** is the deviation of the temperature during a traffic stop from the monthly average high temperature.[8] When included without ***Temp*** in Regressions 15 and 16, ***Temp Diff*** largely mirrors the impact on citation rates that ***Temp*** has in Regressions 13 and 14. When included with ***Temp*** in Regression 17, both temperature variables remain statistically significant, though ***Temp Diff*** loses statistical significance when included with ***Temp*** and all control variables. In total,

[8] As expected, ***Temp*** and ***Temp Diff*** are highly correlated, as higher temperatures will correspond with higher than average temperatures. The correlation coefficient between the two variables is: r = 0.55.

Table 8 Probit analysis of traffic stops, non-linearity

	Dependent variable: did the driver receive a citation during the traffic stop? (1 = yes)				
	(19)	(20)	(21)	(22)	(23)
	Year, zone	Year, zone	Year, zone	Year, zone	Year, zone
Fixed effects					
Temp	**0.0011*****	−0.0001			−0.0001
	(0.0001)	(0.0004)			(0.0004)
Temp^2		**0.0000*****			**0.0000*****
		(0.0000)			**(0.0000)**
Temp Diff			**0.0010*****	**0.0008*****	−0.0001
			(0.0001)	**(0.0002)**	(0.0002)
(*Temp Diff*)^2				**−0.0000****	−0.0000
				(0.000)	(0.0000)
N	130,672	130,672	130,672	130,672	130,672
Chi-Sq	8763.0	8777.0	8631.4	8629.9	8776.8

Marginal effects reported. Robust standard errors in parenthesis. A constant term is included in each specification

Gender, race, shift, weekend and solo variables included in each regression but not reported

***, **Statistical significance at the 99% (95%) level. All estimates exceeding a statistical significance of 95% are in bold

considering a deviation of actual temperature from an expected temperature does not seem to substantially modify the result that citations are more likely to occur in warmer temperatures.

Table 8 considers the possibility of a nonlinear relationship between temperature and the propensity to issue a citation.[9] ***Temp*** exhibits a convexity when a squared term is included—that is, the rate at which officers issue citations increases as temperatures rise. ***Temp Diff*** exhibits the opposite, as the squared term is negative. When all four terms are included in the same specification, the only term maintaining statistical significance is the squared term for ***Temp***. Ultimately, this result further confirms the propensity for officers to issue citations as temperatures rise, and introduces the possibility that this effect becomes particularly large at particularly high temperatures.

4 Conclusion

Heat influences human behavior; being humans, police officers are no exception. In this study, the heat effect bears itself out in police behavior through the increased likelihood of issuing a citation as temperatures increase. The magnitude is nontrivial;

[9] Note that Table 8 reports only the partial effects for ***Temp***, ***Temp Diff*** and their squared terms. A full set of control variables are included in each regression, and their estimates are effectively identical to the estimates for them in Table 7.

depending upon the particular specification, a one-standard deviation increase in temperatures leads to a several percentage point increase in the likelihood of issuing a citation, an increase comparable to the discrepancy in citation rates between races. Most importantly, the heat-influenced increase in citation rates cannot be attributed to the possibility of increased aggressive driving as temperatures rise.

Any factor shown to disturb the even enforcement of the law is worth exploring for that reason alone; that the factor here is largely exogenous should do nothing to diminish that fact. Nevertheless, the scope of plausible policy prescriptions is necessarily limited by the broadly uncontrollable nature of the weather. Addressing, say, racial disparities in the enforcement of the law seems fundamentally different than mitigating discrepancies resulting from higher temperatures. Furthermore, insofar that temperatures are broadly increasing, so too is the possibility of distortions in the enforcement of the law.

Additional research into the impact of heat upon law enforcement is needed to accurately capture the nature of this relationship. While empirically robust, this study nevertheless considers 5 years of traffic stops in one American city. Expansion on all margins—police/civilian interactions beyond traffic stops, including more than 5 years, in a wide range of locales—better allows the true nature of the heat effect on officers to be determined. Still, this study establishes an important first look at temperature and the enforcement of the law.

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