Understanding Interpersonal Violence Using Hot Temperatures in Mexico

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François Cohen[a] and Fidel Gonzalez[b]

Abstract

The reasons behind crime have been extensively theorised with few empirical validations. We exploit the correlation between temperature and crime in Mexico to understand criminal behaviour in a developing country context. Crime rates increase linearly with temperature, which contradicts the belief that only high temperatures cause disturbances. A large share of weather-induced crimes is caused by alcohol consumption (18%) and changes in time use during weekends (20%). We find more failed attempts during hot days, while the ratio of final convictions over initial accusations is stable across the temperature range, suggesting that opportunities do not proliferate. Yet, in 40% of cases, higher crimes rates during hot days are offset by lower crime rates on the following days, plausibly because crime has decreasing returns. Taken together, these results suggest that social circumstances strongly matter to crime. Security-driven policies may not always be the best response to large fluctuations in crime rates.

Keywords: extreme weather; temperature; crime; distributed lag model; routine activities.

JEL codes: K42, K49, Q54, Q56.

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a: Institute for New Economic Thinking at the Oxford Martin School and Smith School of Enterprise and the Environment, University of Oxford, Oxford, UK.

b: Sam Houston State University, Houston, USA.

Introduction

Increasing safety and reducing violence constitute a priority in Latin America, where the direct cost of criminality has been estimated at 3.6% of GDP (Inter-American Development Bank, 2017). Since 2006, the Mexican government has waged a war against drug traffickers with increased means given to police and the military. However, recent studies show that the war on drugs has been costly and unsuccessful, calling for renewed, evidence-based policy-making to deal with criminality (Dobkin et al., 2009; Guerrero, 2011; Escalante, 2011; Merino, 2011; Quah et al., 2014; Dell, 2015).

In this paper, we attempt to understand the motives behind the range of criminal offenses committed in Mexico, an emerging country characterised by high levels of interpersonal violence. We consider the main channels previously advanced to explain criminal behaviour: emotional distress leading to anti-social behaviour; social contexts encouraging criminal attitudes; low sanctions and impunity; and the possibility to obtain high rewards from crime. While these channels have been extensively theorised, quantifying their contribution has been difficult. Using a large dataset of municipality-level daily data, we take advantage of surges in crime rates concomitant to hot days. We use this phenomenon as quasi-experimental evidence to assess the reasons behind sudden increases in criminality. In our dataset, the crime rate is around 80% higher during hot days above 32°C than for any other day.

We show that changes in the social environment of criminals explain strong fluctuations in crime rates. This is an important result because the most commonly-cited explanation for the daily correlation between crime and temperature is that heat produces biological alterations that can lead to aggressive behaviour (e.g. Bell 1980; Vrij, Van der Steen and Koppelaar, 1994; Anderson, Anderson and Deuser, 1996; Anderson *et al.*, 2000; Anderson, 2001; Baylis, 2015; Baysan *et al.*, 2015). In our regressions, crime rates increase linearly in temperature. An increase of one degree Celsius increases the accusation rate of all types of crimes by 1.3%. In all the domains where temperature has been found to affect human physiology (e.g. health, productivity, learning abilities), the relationship is non-linear and effects are strong at the extremes. If human irritability was the sole determinant of the temperature-crime correlation, temperature changes should have no effect on crime within the comfort zone of the human body (20-25°C) and increase exponentially further away from this comfort zone. The linear pattern that we find is strong evidence that the temperature-crime relationship cannot be fully explained by physiological aspects. We look at the circumstances of heat-induced crimes to understand where the linear effect comes from. We find that the temperature-crime relationship is stronger during weekends: 20% of all weather-induced crimes would not have happened if hot days had occurred exclusively on weekdays. Moreover, we uncover that at least 18% of weather-related crimes are triggered by an excessive use of alcohol determined by weather conditions. We also find that rapes and sexual aggressions are particularly sensitive to night temperatures, with 35% of weather-induced rapes and sexual aggressions caused at night. Uncomfortably hot days may be as favourable to sexual crime as pleasant nights. These findings on the importance of substance abuse along with day and night time use and align with the modern psychology literature on crime, for which antisocial behaviour is acquired through social learning and heavily relies on antisocial peer associations and activities (Andrews and Bonta, 2014; Akers, 2017).

Our second major contribution is to analyse the economic mechanisms linking social contexts to crime. Our results support the notion that the perceived benefits of committing criminal acts depend on social contexts, which translates into crimes during hot days. We first assess whether hot days have a permanent effect on crime rates. We find that 40% of the peaks in crime rates occurring during hot days are compensated by reductions in crime rates during the following days. Therefore, weather-related crimes can be split between 60% of additional crimes and 40% of displaced crimes. For the additional 60% of crimes, temperatures necessarily alter the underlying utility function of committing offenses. Sociological and economic theories suggest that criminogenic situations may either a) offer higher opportunities; b) impair deterrence; or c) enhance perceived benefits. We find that the proportion of failed attempts increase in temperature and that the conviction to accusation ratio does not depend on temperature, suggesting that it is not easier to commit or to get away with a crime during a hot day. We conclude by elimination (of a and b) that social circumstances must magnify the perceived benefits of heat-related crimes (c), especially through alcohol consumption and changes in activities. This is especially the case for sexual crimes since they happen to be fully additional. The 40% displaced crimes constitute evidence of decreasing returns to crime. For these, we understand that social interactions must intensify criminal acts during hot days. However, criminals prefer not to commit twice the same offense.

To the best of our knowledge, the objectives and the findings of this paper are unique in the literature. We are aware of no other paper that analyses the fitness of competing theories of crime to national-level data, let alone in a developing country context. While a wide literature shows that criminality and aggressiveness rise sharply with high temperatures (e.g. Kenrick and

MacFarlane, 1986; Anderson, 1987; Reifman, Larrick and Fein, 1991; Auliciems and DiBartolo, 1995; Bushman and Groom, 1997; Horrocks and Menclova, 2011 and Ranson, 2014), no other study has fully explored the many channels that could drive this relationship. The closest paper to our research is Jacob, Lefgren and Moretti (2007), which focuses on the decreasing returns to crime. Their results on decreasing returns to crime in the US align with our findings on Mexico.[1]

This study is also the first to analyse the temperature-crime relationship with daily crime data for an entire country. Our unique dataset is extremely rich as it covers 90% of Mexican municipalities for 16 years and consists of about 12 million daily crime rates at the municipality level. Our base model correlates the municipal criminality rate on a given day with the local average temperature on this same day. We use municipality-by-month-of-the-year fixed effects to restrict the analysis to short-term effects and control for a large set of unobservable factors that could explain differences in criminality levels across municipalities and seasons. In complement, we use a distributed lag model to account for displacement effects over 21 days. This additional approach allows us to assess if sudden increases in crime rates are offset by lower crime rates in the following days. We have run these models on ten types of crimes and we provide slightly different conclusions for violent and non-violent crimes, sexual crimes, and drug-related crimes. We finally disaggregate the data to correlate the characteristics of specific crimes and criminals with temperature to perform complementary robustness checks.

Our series of findings have wide-ranging implications for the current debate on rethinking policies against violence in emerging countries. The central idea behind enforcement-driven policies such as waging a “war on drugs” is that criminality is high because impunity is high. Our results show that drastic increases in criminality can develop even when deterrence and opportunities remain stable. Enforcement-driven interpretations omit that criminals are equally or more responsive to immediate private benefits than to delayed punishment. Therefore, focusing on deterrence alone may constitute a suboptimal choice from a policy perspective. The

[1] Jacob, Lefgren and Moretti (2007) report that criminality levels are offset following hot days for the U.S. They emit the hypothesis of decreasing returns to crime. This paper also looks at short-term heat-related crime dynamics and is therefore the second one to do so. We however go one step beyond. Jacob, Lefgren and Moretti (2007) do not have information about impunity levels and cannot discard the eventuality that displacement effects are the product of optimal timing decisions from rational criminals. Our analysis puts in evidence decreasing returns to crime in an unprecedented way. Our research furthermore exemplifies how enforcement-driven approaches may miss out on structural determinants of crime. Our findings (and the ones of Jacob, Lefgren and Moretti, 2007) align with recent evidence from Draca et al. (2018) on the importance of expected rewards in driving crime rates. These authors find that commodity price falls explain significant reductions in property crimes in London.

fact that social circumstances matter so much to explain short-run crime rate fluctuations suggest that urban planning and social policies can reduce criminality if they prevent anti-social peer associations or contribute to lower down victimization risks. While many analysts have already advocated for these elements, our results provide some of the required statistical evidence to endorse this view. We more generally show that private expected benefits matter. Policies that could reduce the private benefits of criminal acts (e.g. reduce the demand for drugs) may be more effective than the ones that increase expected sanctions. As for heat-related violence, our overall findings suggest that climate change may increase every day violence and that policy responses should consider that heat is a risk factor. For example, police should increase surveillance activities during hotter days around areas where crimes have previously taken place. Likewise, awareness campaigns about sexual abuses and rapes should also mention hotter weather as a risk factor. Nonetheless, these conclusions rely on several inferences and more evidence should be gathered on the cost-effectiveness of specific programmes.

This paper consists of six sections. Section I provides a summary of the usual explanations on the roots of crime relevant to our analysis. Section II presents the data available in Mexico. Section III focuses on the role played by social circumstances in driving crime rates. Section IV looks at the economic mechanisms at play. Section V assesses the robustness of our findings while section VI concludes.

I. Related scientific literature

The study of how weather changes can affect interpersonal conflict is not new. Early research by Anderson (1987) shows cross-sectional correlations between high temperatures and crime in the U.S. This phenomenon has also been observed with panel data (Bushman and Groom, 1997) or in other countries such as Australia (Auliciems and DiBartolo, 1995) or New Zealand (Horrocks and Menclova, 2011). Moreover, this relationship persists in very diverse situations, among pitchers in baseball matches (Reifman, Larrick and Fein, 1991) and car drivers (Kenrick and MacFarlane, 1986) to mention a few. Ranson (2014) offers the most recent and comprehensive study of this phenomenon in the U.S. He uses a panel approach with monthly crime and weather data at for about 3,000 counties from 1980 to 2009. The study finds a linear positive effect of temperature on violent crimes and a non-linear effect on property crime. It predicts a drastic surge in crime under climate change in the U.S.

I.A. Physiological vs. sociological explanations

Physiological explanations. The existence of a temperature–aggression relationship in many contexts has conducted researchers to think that high temperatures might consistently interfere with human behaviour. Criminology developed as a branch of biology and traditionally perceived criminals as psychologically dysfunctional (Hirschi, 1986). Naturally, this gave rise to physiological explanations focusing on the biological link between temperature and aggression.

Likewise, modern analyses often interpret the correlation between temperature and crime as caused by physiological factors. For Mexico, Baysan *et al.* (2015) analyse the correlation between temperature and killings by drug-trafficking organizations, homicides and suicides. They find that higher temperatures are associated with increases drug-related killings, homicides, and suicides. They also exploit a quasi-experimental variation in income and find that only killings due to drug trafficking are influenced, albeit weakly, by such variation. Baysan *et al.* (2015) conclude that all three types of violent deaths seem to be triggered by a similar underlying pattern, possibly alterations in human psychology.

Most frameworks for the temperature–aggression relationship revolve around the notion of "crankiness" (Anderson, 2001). In Appendix A.1, we quickly describe different models of social behaviour that are compatible with the notion of crankiness of hot temperatures. The general idea is that high temperatures produce lack of comfort and this would affect the way people perceive things. For example, minor insults would often be perceived as major ones under heat. In this matter, Baylis (2015) analyses one billion tweets in the United States and finds strong evidence of a sharp decline in tweets' moods when temperature is above 70°F. People may also become impatient: Wearden and Penton-Voak (1995) find that time seems to pass faster for people exposed to warmer temperatures. Vrij, Van der Steen and Koppelaar (1994) examine the attitude of police officers while using a firearms training system, at normal and high ambient temperatures. They find that high temperatures result in increased tension, a more negative impression of the offender and aggressive behaviour.

Yet, the physiological channel (built on the crankiness of hot temperatures) is unable to explain why some other factors that create discomfort do not lead to more aggressiveness or criminality. An early study by Bell (1980) looks at the behaviour of 80 male American college students and finds an effect of heat but no effect of noise on aggressiveness. Cold also produces discomfort but there is no statistical evidence that cold might lead to more violence. Anderson *et al.* (2000) and Baylis (2015) argue that asymmetric responses between cold and heat are to be expected because protective measures against cold temperatures tend to be more widespread, while many people do not protect themselves against heat. This explanation is sensible but does not rule out the eventuality that heat and cold may trigger different levers. This poses the question of the specificity of heat on increasing violence.

Anderson, Anderson and Deuser (1996) argue that differences in the physiological response of the human body to cold and heat could explain why heat leads to aggression while cold does not. Appendix A.2 describes a few medical determinants more in detail. It shows that the scientific evidence on the physiological determinants of aggression does not allow making definitive conclusions. However, a physiological channel through which temperature may affect aggression is cognition. A couple of recent economic studies show that cognitive faculties are substantially affected by high temperatures among students passing exams (Park, 2016; Zivin, Hsiang, Neidell, 2015). Moreover, criminal offenses are often characterized by suboptimal choices, in particular a wrong assessment of the pros and cons of committing an offense, e.g. favoring immediate rewards while overlooking the possibility of high sanctions. Any impairment of judgement caused by external factors, such as drugs and alcohol, but also temperatures, might trigger additional offenses.[2]

Sociological explanations. Because any alteration to the social environment concomitant to hot temperatures may confound the temperature-crime relationship, physiological theories on the crankiness of temperatures are only one possible explanation. Applied to the context of ambient temperature, the theory of *routine activities* of Cohen and Felson (1979) implies that temperature-induced changes in performed activities can significantly affect criminality. Cohen and Felson (1979) associate changes in time use to changes in victimization risk. They consider that, in the absence of defenders, offenses can only occur if motivated offenders and suitable targets meet in a specific place and at a specific moment in time. The probability that such encounters occur vary from hour to hour, or day to day.[3] Using U.K. data, Field (1992) interprets the change in crime rates during hot days as resulting from changes in routine

[2] The question of cognitive deficiencies becomes of particular importance for the diagnosis and treatment of sex offenders and child molesters. Yet, little is known about the fundamental differences in the processing of information by sex offenders vs. non offenders (Geer et al., 2000). Calvin and Marshall (2001) note that rapists and sexual offenders constitute a very heterogeneous category of offenders who are unlikely to suffer from the same cognitive distortions.

[3] Furthermore, structural change in routine activities could lead to an increase or a decrease in criminality. Cohen and Felson (1979) argue that a reduction in the time spent on routine activities performed at home in favour of other activities performed away from home was responsible for a significant rise in U.S. criminality rates between the 1960s and the 1970s.

activities. Field (1992) finds a strong correlation between temperature and criminality in the U.K., a country in which temperatures are always mild – they may never be hot enough to trigger any physiological effect. He concludes that criminality increases during hot days in the U.K. plausibly because households spend more time outdoors.

Instead of talking of routine activities, Hindelang, Gottfredson and Garofalo (1978) prefer the term of *lifestyle* to describe the possibility that people's day-to-day activities could explain differences in victimization risk. Concretely, antisocial peer associations and substance abuse are primary determinants of aggression. If antisocial peer associations occur more often during hot days than during cold days, then aggressions conducted in anonymous groups (e.g. hooliganism, gang violence) could become more frequent during high temperatures (Anderson and Bushman, 1997). Likewise, temperatures may be associated with drugs or alcohol consumption, and indirectly lead to more crimes. Lifestyle-based explanations echo modern psychological theories of crime, since these heavily rely on social learning to explain the development of anti-social behaviour in childhood and adolescence (Andrews and Bonta, 2014; Akers, 2017). The personality traits of criminals typically include defiance, hostility, lack of self-control, a weak conscience and an inability to plan or defer gratification.[4] These traits can be exacerbated by the social environment. Time misuse, anti-social peer associations and substance abuse are repeatedly observed among adolescents and young adults that turn into delinquents (e.g. Fergusson et al., 2002; Wasserman, 2003; Osgood and Anderson, 2004; Barnes, 2007).

I.B. Economic mechanisms behind heat-related violence

The above-mentioned theories of the temperature-crime relationship can be reformulated in broader economic terms. Schematically, physiological and sociological factors may either increase the anticipated benefits from committing crimes, or reduce expected costs (e.g. through higher opportunities or reduced sanctions).[5] The physiological theories of "crankiness" imply

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[4] Wilson and Herrnstein (1985) argue that fundamental differences developing during childhood distinguish serious criminals from the general population. In a different fashion, the theory of self-control by Gottfredson and Hirschi (1990) consider that lack of self-control and the inability to defer gratification explain much of the difference between offenders and non-offenders.

[5] The general approach of economics to crime (since Becker, 1968), that criminals are (bounded) rational actors responding to economic (dis)incentives, has been extensively criticised (see Appendix A.3 for more detail). For sure, not all crimes can be easily explained with a rational approach. Some criminals do not seem to act rationally at all (e.g. psychopaths). However, a widely accepted view is that criminal law and its enforcement, hand in hand with the general community, have the responsibility to counter any benefit from breaking the law that could rise from utility maximisation. There should be no rational calculation that would make criminal conducts advantageous (Kramer, 1990). In sociology, social control theories (e.g. Hirschi, 1986) consider that individuals weight costs and benefits of alternative choices and choose the ones that are most likely to maximize their pleasure.

that criminals display a higher taste for violence under heat. Their implicit utility to commit crimes is temporarily altered. In the routine activity theory of Cohen and Felson (1979), crimes mostly happen more because opportunities arise or because deterrence is less effective. Routines have an impact on the expected cost of crime. On the opposite, the lifestyle-based theory of Hindelang, Gottfredson and Garofalo (1978) suggest that crime can also be more frequent because the perceived benefits of crime are context-dependent.

Cost-based interpretations. If judicial systems are imperfect, the expected level of punishment may be insufficient to discourage offenders. There is empirical evidence that criminality is responsive to deterrence, even though the response to deterrence could be moderate. The likelihood of being punished has been found to reduce criminality more than any other measure of deterrence, particularly the severity of the punishment (see Travis *et al.*, 2006, for a literature review and meta-analysis on deterrence).[6] In the case of hot days, the probability of being caught may be different when an act is perpetrated during a cold day rather than during a hot day. This should modify the amount of crimes committed during hot days if criminals act rationally. Other factors than the likelihood of being punished could also suggest that crime increases during hot days because of higher opportunities. For example, if crime attempts are more successful or if experienced criminals time their acts with hot days. Currently, we are aware of no study showing that hot temperatures might actually enhance opportunities and lower deterrence, even though this eventuality cannot be discarded.

Benefit-oriented interpretations. Equivalently, changes in the expected benefits from committing a crime would enter the utility function of rational criminal offenders. Therefore, changes in the benefits from producing a crime should be at least equally important as changes in expected sanctions. However, since sanctions are uncertain and deferred, some criminals could heavily discount future sanctions and be much more sensitive to expected benefits than to deterrence mechanisms (Gottfredson and Hirschi, 1990).

In the medium to the long run, economic studies have shown that temperature influences the marginal utility of committing crimes because inclement weather conditions produce negative

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The choice of illegal actions may be restrained by social factors such as attachment to people or institution, or the belief in the moral validity of the law. Within these social or moral constraints, actors may still make the conscious choice to break the law. In such frameworks, a weakening of social or institutional bonds could also lead to more offenses being committed.

[6] In deterrence theory, three parameters usually determine the efficiency of deterrence: the certainty, severity and celerity of punishment. These is not much evidence on impact of celerity – the fact that a punishment may be applied quickly or not – on the amount of criminal offense being committed (Onwudiwe, Odo and Onyeozili, 2005).

income shocks and subsequently trigger economically motivated crimes. All types of violent and non-violent crimes that are economically motivated are more likely to take place during floods or droughts in economies that are dependent on agriculture (Miguel, 2005; Iyer and Topalova, 2014; Blakeslee and Fishman, 2015). This phenomenon has also been observed in 19th-century Bavaria (Mehlum, Miguel and Torvik, 2006) and during the Mexican revolution (Dell, 2012).[7] A consensus has also emerged that future climate change may trigger new conflicts, both at intergroup and interpersonal levels (see Hsiang, Meng and Cane, 2011; Hsiang, Burke and Miguel, 2013; and Burke, Hsiang and Miguel, 2015a for detailed reviews).

In the short run, expected benefits may also be a function of temperature fluctuations, e.g. because of a higher taste for violence or changes in social contexts. Expected benefits could also be volatile because there could be decreasing (or increasing) returns in committing the same type of crime twice, or because the pool of available opportunities may be finite. Jacob, Lefgren and Moretti (2007) use a panel of weekly crime data for 116 jurisdictions in the U.S. from 1995 to 2011 to analyse the timing of crimes. They rely on weather data to identify pikes in crime rates and assess if the pikes in one week are followed by more crimes in the following weeks (due to imitation and retaliation) or by less crime in the following weeks (due to decreasing returns). They find that warm weeks with above average crime rates are followed by weeks with below average crime rates. Displacement effects could account for about 40% of all violent crimes committed during one week. They explain this result by arguing that committing the same type of crime again does not provide the same benefits.[8]

For now, we have reviewed four channels that can explain part of the temperature-crime correlation: physiological explanations; sociological explanations; changes in law enforcement; and changes in the rewards derived from crime. These explanations are not fully orthogonal since physiological and sociological explanations may relate to a series of (economic)

[7] We can furthermore draw a parallel between evidence that weather shocks could influence interpersonal violence and the increasing evidence that inclement weather is associated to civil and armed conflict throughout the world and for different periods of time. A consensus has now emerged that increases in temperature and reductions in rainfall are associated to increases in civil unrest (see Burke, Hsiang and Miguel, 2015a and Dell, Jones and Olken, 2014, for a complete review of this literature).

[8] Jacob, Lefgren and Moretti (2007) also analyse the case of property crimes along the lines of the permanent income theory: if a crime produces an increase in permanent income, the latter will reduce the financial need for committing more crimes after the first crime is committed. Jacob, Lefgren and Moretti (2007), however, cannot discard the possibility that lower chances of getting caught during hot days explain displacement effects, i.e. that the timing of crimes is endogenous. Likewise, the pool of possible criminal offenses could be temporarily exhausted after the crime pikes, explaining lower crime rates.

mechanisms to explain shifts in crime rates. In the remaining of this paper, we test whether the statistical evidence supports these channels, using data for Mexico.

II. Data and summary statistics

Our statistical analysis correlates daily data on criminal activity with temperature, rainfall and humidity data at municipality level in Mexico from 1997-2012.

II.A. Criminality data

The criminality data comes from the Judicial Statistics on Penal Matters of Mexico published by the National Institute of Statistics and Geography (INEGI, 1997-2012). The data comes from the administrative records of the Criminal Courts of First Instance (*Juzgados Penales de Primera Instancia*). These are the courts where the initial criminal accusations are recorded, prosecuted and eventually sentenced by a judge. Our data contains information on accusations, prosecutions and convictions. Prosecutions include information on presumed criminals that have gone through a trial, and convictions are those found guilty. On the opposite, the data on accusations is recorded at an earlier stage and is more likely to include information on crimes for which nobody is sentenced. In this paper, we concentrate on the accusations because we are primarily interested in the occurrence of crimes. However, we use the data on prosecutions and convictions at the end of this paper, when we study the treatment of identified criminals by the judicial system.

The accusations and prosecutions datasets contain detailed information on the type of crime, the intentionality of the crime (e.g. premeditation, negligence) as well as the municipality, state, day, month and year where and when the crime took place. The dataset also includes socioeconomic information of the person processed for a crime and the psychophysical status of the offender while committing the crime. We aggregate the data at municipality level to perform most of the statistical analyses. We however use the (disaggregated) crime-level datasets in section V (robustness).

The original dataset contains a wide range of over 400 detailed crimes types which we have aggregated into broader crime categories. Table 1 shows the ten categories that we use in our analysis, they cover between 70% and 80% of the total number of crimes recorded in the original dataset. Next, we divide the overall and by-type number of crimes in each day by the yearly county population to compute daily accusation crime rates per million inhabitants. The population data comes from the Mexican censuses of 1995, 2000, 2005 and 2010. We perform a linear interpolation of the population for the years between two censuses and after 2010 to obtain estimates of the Mexican population of each municipality in each year between 1990 and 2012.

Table 1 displays the average accusation and prosecution rates by type of crime and according to a few circumstances surrounding offenses for the period 1997-2012. The average accusation rate in Mexico was around 5.8 accusations per million inhabitants. The most common type of crime was theft (1.68 accusations per million inhabitants), followed by injuries (0.85) and property damage (0.48). Most crimes were intentional crimes with no premeditation.[9] There was a slight increase (by about 9%) in criminal offenses over the weekend. In general, the prosecution rate was 30% lower than the accusation rate.

[TABLE 1 ABOUT HERE]

Figure 1 provides information of the geographical distribution of accusations at municipality level. In general, northern and coastal states (Baja California, Sonora, Sinaloa, Chihuahua, Nayarit, Colima, Nuevo León and Tamaulipas) registered a higher intensity of offenses.

[FIGURE 1 ABOUT HERE]

II.B. Weather and climate data

We have gathered daily temperature and precipitation data from the National Climatological Database of Mexico. Records correspond to the data from around 5,500 operating and formerly operating land-based stations in Mexico. However, the data has been aggregated at municipality level to match the criminality data.[10] Figure 2 below presents the historical distribution of daily average temperatures in Mexico from 1997 to 2012.[11] The data presented below is used in the econometric models later on. We have constructed 13 temperature bins: the "less than 10°C"

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[9] The terms in Table 1 come from the administrative records and correspond to a judicial interpretation of intentionality. They do not rely on a purely psychological definition where intentionality would stand for a reflective process, and unintentional actions would strictly derive from either automatic or spontaneous responses (e.g. reflexes).

[10] We match the municipalities in Mexico with the closest land-based stations. We calculate the longitude and latitude of the centroid of each municipality (averaging the coordinates of all the locations that are part of a municipality) based on the data from the National Geostatistical Framework (*Marco Geoestadístico Nacional*) of the INEGI. Then we compute the distance between this centroid and all the land-based stations of the climatological data. We consider a land-based station to be within a municipality if it is less than 20km from its centroid. For municipalities that are isolated, we may have less than 5 active stations in the 20km radius. In this case, we match each municipality with the five closest stations within a maximum radius of 50km. Once we have identified the land-based stations relevant to a municipality, we compute the daily mean temperature and precipitation levels in a municipality by averaging the records of all the stations be relevant to a given municipality.

[11] The daily average temperature is defined as the average between the maximum and the minimum temperature of that day, following recommendations by the World Meteorological Organization (2011).

bin is the lowest, the "more than 32°C" bin the highest, and there are eleven 2°C bins between them. The climate in Mexico is hotter than in most countries. Furthermore, Mexico is expected to be heavily impacted by climate change, and therefore to remain one of the hottest spots in the world. Days between 16 and 18°C are the most frequent, and the daily mean temperature oscillates between 14 and 22°C during more than half of the year. At the extremes of the distribution, there are 5.7 days per year below 10°C (50°F) and 1.7 days above 32°C (90°F) on average.[12]

[FIGURE 2 ABOUT HERE]

III. Weather-induced crime and social circumstances

In this section, we study the response of crime rates to sudden changes in temperature. We are exclusively interested in the immediate effect of temperature on crime, with no consideration given to short-term dynamics (i.e. what happens on the following days). This section aims to understand why, during a hot day, the crime rate increases, no matter whether crimes are additional of not in the end. We find a linear relationship between crime and temperature, largely influenced by social factors such as alcohol consumption or spare time allocation during weekends.[13]

III.A. Contemporaneous model

We correlate the daily accusation records with daily temperatures while controlling for most municipality-level changes in average accusation rates. We use the data on accusations, and not prosecutions, since we think that it is a better reflection of the quantity of crimes being committed in Mexico. Daily records ensure correct identification of the causal effect of temperature on accusation in the short run while maintaining constant all sorts of socioeconomic factors influencing criminal behaviour such as income, social inequalities, or the effectiveness of the legal system. More precisely, we use fully interacted municipality by month by year fixed effects. These fixed effects control for all unobservable characteristics of

[12] Deschenes and Greenstone (2011) provide a distribution of daily mean temperatures in the U.S. On average, temperatures are much lower: there are around 120 days with a mean temperature below 10°C and 1.3 days with temperatures greater than 90°F (32.2°C).

[13] In section 5, we use the distributed lag model and the latter account for displacement effects. The results of section 4 are similar to the ones we obtain when running the distributed lag model when looking exclusively at the values for the coefficients corresponding to contemporaneous temperatures (i.e. not the lagged values).

a municipality for a specific month in a given year: only the municipal level variations from one day to the other within a month remain to be explained. The model is as follows:

$$(1) \qquad Y_{i,d,m,t} = \theta . T_{i,d,m,t} + \mu_{i,m,t} + \varepsilon_{i,d,m,t}$$

where $Y_{i,d,m,t}$ is the accusation rate of municipality i on day d of month m and year t, θ is a vector of parameters, $T_{i,d,m,t}$ is a vector of climatic variables that we discuss in detail below, $\mu_{i,m,t}$ is a vector of municipality-by-month-of-the-year fixed effects, and $\varepsilon_{i,d,m,t}$ is the error term. Heteroskedasticity is accounted for by computing cluster-robust standard errors. Each cluster corresponds to a given municipality. The regression coefficients need to be weighted for the estimates to be representative of the population. Furthermore, $Y_{i,d,m,t}$ is noisily estimated in small municipalities and the effect of such noise on the estimation is mitigated with the use of population-based weights. We use the square root of the population as a weight.[14]

The vector $T_{i,d,m,t}$ includes our climatic variables of interest. To test for non-linearity in the accusation-temperature relationship, the most conservative approach consists in using temperature bins to specify the relationship between temperature and accusation. This approach has been done in other applications, such as mortality and energy demand (e.g. Deschenes and Greenstone, 2011; Cohen and Dechezlepretre, 2017). The model requires as many dummy variables in $T_{i,d,m,t}$ as temperature bins, each one taking the value of 1 when the day's temperature falls within the range of the bin. We use 2-Celsius-degree temperature bins (e.g. 10-12°C, 12-14°C) to construct the vector $T_{i,d,m,t}$. As per Figure 1, the lowest bin covers days with temperature below 10 Celsius degrees, and the highest bin covers days with temperature above 32 Celsius degrees.

III.B. Results of contemporaneous model

The general results obtained with the contemporaneous model are reported in Figure 3. We find a linear relationship between the average daily temperature and accusation rates. An increase by 1 degree Celsius roughly increases the daily accusation rate by 0.08 crimes per million inhabitants. This roughly corresponds to a 1.3% increase in the average accusation rate. The difference between a cold day (<10°C) and a hot day (>32°C) is sizeable: it corresponds to an increase of 1.9 daily accusations per million inhabitants, roughly equal to a third of the average daily accusation rate. This model predicts that if all days had been below 10°C, the accusation

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[14] Using total population instead of the square root has no significant impact on the results.

rate would have been 14% lower (by 0.81 points).[15] The weather appears to be a very good predictor of the frequency of criminal activities.

[FIGURE 3 ABOUT HERE]

We also break down the accusation rate by type of crimes. Figure 4 reproduces the regression that correlates on-the-day temperature with accusation rates for the ten types of crimes listed in Table 1 (in the data section). To ease comparability, each graph has been rescaled based on the average accusation rate observed in the data for each type of crimes shown on Table 1. We find that accusations for violent crimes (homicide, injury, rape and sexual aggression and possession of weapons) have the strongest correlations with hot weather: the average accusation rate during unusually hot days (>32°C) increases 50% compared to unusually cold days (<10°C). We also find a correlation with hot temperatures and property damage, thefts, and drug-related crimes but the magnitude of the impacts is smaller. We find no conclusive evidence for car thefts, manslaughter and kidnapping. We may lack statistical power since these events are less frequent in our dataset.

[FIGURE 4 ABOUT HERE]

III.C. A sociological interpretation

The linearity of the estimates for all crime types casts serious doubt on the validity of the physiological channel in explaining the full breadth of the temperature-crime relationship. A large body of epidemiological research has shown that ambient temperatures have a strong impact on human health when temperatures become uncomfortably high or low. The correlation between mortality (or morbidity) and temperature is U-shaped (e.g. Curriero et al., 2002; Hajat et al., 2006; Hajat et al., 2007; McMichael et al., 2008; Deschenes and Moretti, 2009; Cohen and Dechezlepretre, 2017). Likewise, economists have found that the human ability to perform physical and cognitive tasks was impaired by extreme temperatures (e.g. Burke, Hsiang and Miguel, 2015b; Zivin, Hsiang, Neidell, 2015; Park, 2016). Within the comfort zone of the human body (at 20-25°C), effects are mitigated by thermoregulation. The response function that we uncover does not match the expected U-shape corresponding to alterations of bodily functions. The assumption of a physiological effect triggered by the "crankiness" of unusual temperatures presupposes that effects increase heavily at the extremes. On the other side, they

[15] This calculation takes into account the value of the coefficients displayed in Figure 3 and the distribution of temperatures throughout the year in Mexico, as per Figure 2.

should be cushioned by thermoregulation within and close to the comfort zone of the human body. If we account for the wide availability of protection measures against cold (i.e. clothes), effects could be flat for low temperatures and then increase sharply for very high temperatures. This is not what we record.

Analyses below show that temperatures are associated with changes in activities. We focus on differences between weekdays and weekends, and alcohol consumption.[16]

***Weekdays vs. weekends*.** Weekday activities are constrained by work obligations whereas weekend activities can more easily adapt to good or bad weather. Therefore, time allocation for criminals and their victims is likely to be more responsive to changes in temperature during weekends.

Figure 5 shows the separate effects of on-the-day temperature for weekdays (left panel) and weekends (right panel). We find that both weekdays and weekends are sensitive to changes in temperatures, but that the relative effect of hot days during weekends is about 60% higher than the effect of hot days during weekdays. These curves are statistically different from each other.[17]

[FIGURE 5 ABOUT HERE]

If all days have had a temperature below 10°C, our model predicts that the accusation rate would be lower by 11.5% during weekdays, and lower by 20.1% during weekends. The predicted accusation rates from our econometric model suggest that around 40% of weather-induced offenses occur during weekends.[18] We can calculate the proportion of heat-related crimes that occurred in weekends and would not have occurred if all days were weekdays. This roughly represents 20% of all weather-induced crimes.[19] This is a clear indication that changes in time allocation associated with weekends are a contributing factor to heat-induced accusations.

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[16] We also look separately at minimum and maximum temperature in the robustness checks (section V), and find a strong response of sexual crimes to minimal temperatures. This suggests that temperatures may influence activities undertaken at night, leading to additional criminality through this channel. Night temperatures are much less likely to be hot enough to produce a physiological response leading to aggression.

[17] The effect that weekend accusation rates are more sensitive to temperatures than weekday accusation rates can also be found when crimes are broken down by type of crime. We have observed no strong differences in this pattern for different type of crime, and decided not to report these results for the sake of concision.

[18] Our model predicts that, if all days had a temperature below 10°C, then the accusation rate would have been lower by 0.65 points during weekdays and by 1.24 points during weekends. It follows that the annual weather-induced accusation rate per million inhabitant is 297.6, of which 128.5 occur during weekends (128.5/297.6=43%).

[19] In the previous footnote, we have already calculated that the weather-induced accusation rate is 0.65 accusations per million inhabitants during weekdays and 1.24 accusations during weekends. If weekend days had been weekdays, the annual accusation rate would have been lower by 0.61 points (1.24 – 0.65) per weekend day. With

Psychophysical status. Higher alcohol consumption or drug usage could partly explain crime rates during hot days. Our dataset reports whether the offenders were in a normal state, drunk or consumed drugs.[20] Figure 6 separately reports the results of the contemporaneous model for offenders in normal state (left panel) and drunk offenders (right panel).[21]

The on-the-day correlation between accusation rates and temperatures is twice steeper for drunk offenders as compared to the ones in a normal state. We find that, out of the average 4.53 daily accusations per million inhabitants conducted by offenders in normal state, 0.53 would have never happened if all days had registered temperatures below 10°C, therefore representing 12% of offenses. For drunk offenders, we find that 0.23 out of the 0.82 daily accusations per million inhabitants would have never happened, amounting to nearly 30% of all alcohol-related accusations. These figures equally suggest that 30% of all weather-induced accusations are undertaken by drunk offenders.[22] Simple calculations allow deducting that there would be 18% less weather-induced crimes if alcohol use was not correlated with high temperatures.[23] This figure is substantial.

[FIGURE 6 ABOUT HERE]

IV. The economic function of social contexts leading to crime

The previous section shows that daily criminality levels are volatile largely because social circumstances are changing, as exemplified by the observed shifts in time allocation and alcohol consumption. This section aims to interpret the economic function that these changes in social activities play in determining crime rates.

104 weekend days in the year, this corresponds to a reduction in the annual weather-induced accusation rate (of 297.6) by 61.2 points. This is equivalent to a 20% reduction in weather-induced accusations.

[20] The information is the one recorded by the instance courts as collated by the police. It is often based on the assessment of the victim(s) or of witnesses. Also, the recording of a crime may be concomitant to an arrest, and then the psychophysical status of a criminal may have been directly assessed by the police. This is very likely in crimes such as drug possession or the possession of weapons. Some crimes committed without any witness may have been performed under the influence of alcohol or drugs, but might not be recorded as such.

[21] We are not reporting the results for drugged offenders because there are too few offenses committed under the influence of drugs to find statistically robust evidence for this category. We performed the regression for drugged offenders. Results were very high in magnitude but also imprecisely estimated. This is why and we do not report them for concision.

[22] This is 0.23 / (0.53 + 0.23)

[23] This is the share of weather-induced crimes that are committed by drunk offenders (0.30), multiplied by the relative propensity of drunk offenders to commit weather induced crimes vs. offenders in normal state: (0.30 – 0.12) / 0.30.

IV.A. Distributed lag model

Up until now, we have not questioned if the effect of heat on crime is just temporary – because people simply meet more on hot days for activities that they would have undertaken anyways – or if effects are persistent. A persistent effect would suggest an alteration of the underlying utility function of crime. In this subsection, we explore the effect of hot days on the crime rate of subsequent days.

Deschenes and Greenstone (2011) suggest using a distributed lag model look at displacement effects. We use a model that considers all temperature bins and include 20 lags for each bin. We chose the number of lags to include the past 3 weeks.[24] The equation used to account for short term dynamics is the following:

(2) $$Y_{i,d,m,t} = \sum_{k=0}^{K=20} \sum_{s} \theta_{s,-k}.B_{s,i,d-k,m,t} + \sigma.P_{i,d,m,t} + \mu_{i,m,t} + \varepsilon_{i,d,m,t}$$

where the subscript *s* stands for the various temperature bins, and $B_{s,d-k,i}$ is a dummy variable equal to one if the temperature in day (*d-k)* of district *i* falls within bin *s*. Furthermore, we use on-the-day average precipitation ($P_{i,d,m,t}$) to control for the confounding effect of precipitations on accusation. Due to the lag structure of the model, the effect of an unusually cold or hot day on accusation is the sum of all the coefficients for the contemporaneous and lagged variables representing the temperature bins at the extreme of the spectrum.[25]

IV.B. Results of distributed lag model

Figure 7 reports the cumulative dynamic relationship between temperature and accusations over 21 days. It is obtained by adding the effect of each temperature bins for all its lags in a distributed lag model.

[FIGURE 7 ABOUT HERE]

As in the contemporaneous model, we also find a correlation for temperature and accusations. Yet, the average estimated effects have flattened. At the extremes, the differential between unusually hot and cold days (>32°C vs. <10°C) is of 1.2 crimes per million inhabitants with the

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[24] In Appendix B.1, we allow the number of lags to vary between 0 and 30. We find that results are globally robust beyond 20 days. We observe that offenders delay action for about a week if days are cold, or accelerate them during hot days. Moreover, we observe that there might be recidivism or retaliations within 3 weeks: some of the initial effects are accentuated during the third week. Effects seem to stabilize past 20 days.

[25] This type of model is applicable in our case since we have daily accusation and prosecution rates, daily average temperatures for 16 years and for the vast majority of municipalities in Mexico. Our very large sample allows overcoming the multicollinearity problems arising when many lags and temperature bins are considered simultaneously.

distributed lag model, against 1.9 crimes per million inhabitants with a simple correlation with contemporaneous temperatures. The distributed lag model predicts that if all days had been below 10°C, the accusation rate would have been 8% lower (by 0.46 points)[26]. We had calculated this same statistics with the contemporaneous model in section III.B and had found a 14% reduction (by 0.81 points). Therefore, about only 60% of the weather-related crimes registered with the contemporaneous model are truly additional.

Figure 8 focuses on the short-term dynamics. It presents how the effect of days below 10°C (left panel) and above 32°C (right panel) on accusation attenuate within 21 days. Whereas there is a high correlation between on-the-day temperature and accusations, higher accusation rates are observed on the days following a very cold day (left panel), and lower accusation rates are observed on the days following a very hot day (right panel).

[FIGURE 8 ABOUT HERE]

In fact, the additionally of weather-induced crimes may strongly vary according to the type of crime. Figure 9 provide the results of the distributed lag model for different types of crimes. We lose efficiency when adding many lags and breaking down the results by type of crime, especially for manslaughters, kidnappings, and possession of weapon. For property damage, thefts and homicides, results are very clear and suggest absolutely no additionality. On the opposite, rapes and sexual aggressions appear to be fully additional. There is also an effect of unusually cold weather on drug-related crimes.[27]

[FIGURE 9 ABOUT HERE]

IV.C. An economic interpretation

The weather may play a different function in the fluctuations in crime rates for the 60% additional crimes and the 40% displaced crimes.

Additional crimes. For additional crimes, ambient temperatures seem to influence the underlying utility function of crime. This underlying utility function may have been altered in two ways: either the perceived benefits of crime have been enhanced, or the expected cost of committing a crime has reduced. Hereafter, we provide evidence that the cost of crime may not

[26] This calculation takes into account the value of the coefficients displayed in Figure 7 and the distribution of temperatures throughout the year in Mexico, as per Figure 2.
[27] In section V, we find that temperatures below 0°C degrees are responsible for this effect, suggesting that drug crop production may suffer from cold.

be substantially affected, and conclude by elimination that the perceived benefits must be enhanced.

We assess if the expected cost of crime changes according to temperature by looking at punishments afterwards. To do so, we compare the data on accusations with the data on prosecutions and convictions. First, we look at the change in the proportion of criminals that go to trial (the prosecutions) over the number of accusations initially registered. Second, we look at the share of criminals that are found guilty during their trial (the convictions) as a proportion of accusations. We run two econometric specifications in the same vein as equation (1).[28] We change the dependent variable to (i) the proportion of prosecuted criminal over the proportion of criminals initially accused; and (ii) the proportion of finally convicted criminal over the proportion of criminals initially accused. These models are weighted with the average number of accusations registered in the municipality of interest, in month *m* and year *t*, so that results are representative of the number of accusations. We correlate these dependent variables with the temperature on the day of the crime.

Results are provided on Figure 10, with prosecutions in the left panel and convictions in the right panel. We find no statistical difference between the prosecution and conviction rates for crimes committed during cold vs. hot days, implying that the chances of being caught are not influenced by temperature. If criminals were optimally timing their acts as a function of temperature, we would expect a stronger correlation between accusations and temperature than for prosecutions and convictions and temperature. This is not what we find. This strongly suggests that hot days do not provide particularly better opportunities than cold days to commit most criminal offenses.[29]

[FIGURE 10 ABOUT HERE]

Considering that Mexico is characterised by high levels of impunity, it is not surprising that the statistical evidence suggests that weather-related crimes are not a direct response to changes in deterrence levels. We furthermore found that 30% of all weather-related crimes are committed by drunk offenders (section III.C), and could only attest of an additional effect of temperatures for rapes and sexual aggressions, which are particularly impulsive crimes (in section IV.B). A

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[28] We do not use a distributed lag model since we focus on the contemporaneous circumstances of crime.

[29] A similar result can be obtained by running separately regressions for accusations, prosecutions and convictions and comparing the steepness of the temperature-crime curves relative to their average crime rates. This alternative strategy allows accounting for the fact that some days do not record any accusation/prosecution. In addition, while results tend to lose precisions when breaking down crimes by type or with distributed lag models, they lead to the same general finding.

complementary analysis in section V (robustness) goes in the same direction. We uncover that failed attempts to commit crimes are more common during hot days, corroborating the general finding that it is not easier to commit a crime when temperature is high.

By eliminating the hypothesis that criminals act more during hot days because the expected costs might have reduced, we can conclude with some confidence that the expected benefits of committing crimes must be influenced by the activities that correlate with high temperatures. The perceived benefits of some crimes would therefore be context-dependent. The increase in expected benefits suggested in this section could also stem from a higher taste for violence due to the alleged biological effect of temperature and aggression. However, this channel does not really fit with the evidence of the section III.

Displaced crimes. We interpret the 40% of weather-related crimes that are displaced crimes as the confirmation of the importance of social circumstances and perceived benefits to explain crime rate fluctuations. First, temperature seem to accelerate the timing of crimes because people meet more often during hot days, suggesting that crime happens within a particular social context, in line with the routine activity or lifestyle-based approaches to crime. Second, once the crimes are committed on hot days, a large share of offenders decide not to act again (at least in the short run). Since the cost of committing a crime (e.g. impunity levels) appears to be stable in our analyses, offenders seem not to act again because the marginal benefit of committing a crime is a decreasing function of the number of crimes already committed by an individual – i.e. there are decreasing returns to crime. This mechanism is described in Jacob, Lefgren and Moretti (2007) for the U.S. Our results by type of crime are consistent with this interpretation. Property crimes and theft usually provide increases in income that reduce the need for more crimes to be committed in the short-run. Economic motivations may be temporally satiated. In the case of homicides, for which we find full displacement, the same person cannot be killed twice. The value of killing again might be null, from the offender's perspective, once the first homicide has been successful. In addition, the full displacement of homicides suggests that a physiological effect of temperatures on aggression is less likely to operate. This is because higher aggressiveness should randomly target victims in the wrong place at the wrong time. The available evidence for full displacement suggests that high temperatures do not translate into murders perpetrated at random.

V. Robustness

V.A. Internal validity

The results presented above are robust to several factors, detailed below, that could bias the analysis.

Under-reporting. A recurrent problem using judicial data, in particular from developing countries where trust in institutions is low, is that victims systematically under-report crimes to local authorities. Table 1 and Figure 1 strongly underestimate victimization levels in Mexico. According to the 2016 Mexican Survey on Victimization and Perception of Public Safety, only about 10% of crimes would be reported to public authorities.[30] For the purpose of this paper, systematic under-reporting requires interpreting the results in relative terms more than in absolute terms (or scaling up some results); else, we would significantly underestimate the extent of heat-related crime. However, the main problem with under-reporting is that our estimates of the temperature-crime relationship can be biased if under-reporting is correlated with temperatures. This can be the case if victims do not bother reporting crimes when temperatures are unreasonably hot or cold. We could therefore underestimate the proportion of crimes committed during hot and cold days.

Reasonably, uncomfortable temperatures should not affect the decision of reporting major crimes such as homicides, rapes, or kidnappings. In the 2016 Mexican Survey on Victimization and Perception of Public Safety, about 40% of victims do not report crimes for serious reasons such as lack of evidence (10.3%), fear of retaliations (7.9%), distrust of authorities (17.1%) or even a hostile attitude of authorities (4.4%). For homicides, McCord, Garg and Monfort (2018) look at the correlation with on-the-day temperature using data from the Mexican death statistics. Their results for homicides are very similar to the ones we found. Since mortality data is less subject to under-reporting than judicial data, finding similar effects across both datasets suggests that there is no bias caused by a correlation between temperature and under-reporting for serious crimes.

[30] While relying on a different methodology making international comparisons difficult, the U.S. Department of Justice estimates that 58% of crimes are not reported to the police. The under-reporting rate in Mexico (about 90%) is therefore much higher than in the U.S. The very low reporting rate in Mexico is plausibly due to much lower trust in institutions, lower means given to police, higher social exclusion and frequent exposure to delinquent acts. Based on Transparency International figures, Mexico ranks 135th over 180 in the corruption perception index of 2017, tiding with Russia. The United States rank 16th.

The risk of bias could be higher for less serious crimes. We know that some people decide not to report a crime because they think the judicial system is burdensome. This usually explains why petty crimes are less reported than serious ones.[31] Adding uncomfortable temperatures to the administrative burden could make reporting even more of a hassle. In practice, we find a similar shape in the temperature-crime relationship for serious and less serious crimes. The fact that the curves are comparable suggests no bias due to under-reporting.

There are good reasons to think that the correlation between temperatures and under-reporting is weak or inexistent for petty crimes. First, since most of the population does not report petty crimes, the subgroup of people that follows that route must display strong internal motivation. After all, they are reporting crimes in spite of the many factors (fear of retaliations, distrust in police, lack of evidence, long formalities…) that should have deterred them. The people that are more likely to report a crime are therefore less likely to be influenced by minor issues such as temperature. Second, crimes are rarely directly reported at the police station just after they have happened. Usually, people call the police. While the decision to go to the police station may depend on the weather, the decision to call the police is much less likely to depend on outdoor temperature. Provided that the police has come to help, or that there is no immediate need for assistance, victims can formally report the crime later on at the station, e.g. on the next day or on the following days.

This element is interesting for identification since under-reporting should be correlated with the temperature on the days following a crime. We can therefore partially control for under-reporting by controlling for the temperature of the following days. Below, we provide the results of a model that includes the temperature on the day of the crime and temperature leads up to 7 days after the crime to account for under-reporting. Figure 11 sums up the effect all the coefficients. The final effect displayed is the one for 8 days of temperature at the same level as when the crime was committed. If there were an under-reporting bias, leads should attenuate the correlation between temperature and crime, since an unusually cold or hot day following a crime should reduce the likeliness that a crime is reported on the following day. We do not find any such effect: the estimates found are not statistically different from the baseline results (long dashes).

[31] In the 2016 Mexican Survey on Victimization and Perception of Public Safety, about 32.8% of victims do not report crimes because they think that reporting is a loss of time and 8.3% because formalities are long and difficult. This may explain differences in reporting according to crime gravity. In the same survey, car thefts were reported in 77.5% of cases, vs. 9.4% for other (lower value) thefts; rapes in 19.0% of cases vs. 5.4% for sexual aggressions.

[FIGURE 11 ABOUT HERE]

Omitted variable bias. The results found for temperature could reasonably be confounded by other environmental factors correlated with temperature, especially precipitations, humidity or pollution. In Appendix B.2, we check if our results are partly imputable to precipitations. When adding precipitation bins in the contemporaneous model and their lags in the distributed lag model, we find the exact same effect of temperatures on criminality. Therefore, our results are not confounded by precipitations. We however find a small impact of precipitations on on-the-day criminality: days with high levels of precipitations (>20mm) experience lower criminality rates by around 0.4 crimes per million inhabitants compared to days with no precipitation. This represents around 6.6% of the average daily crime rate in Mexico. However, this impact fades away in the distributed lag model, i.e. after 21 days. We also ran an alternative specification where we also control for humidity (evaporation levels) and find no statistically significant impact on criminality at 21 days. This seems to confirm that human physiology is not at play since humidity strongly influences perceived sensations of heat. Looking at the confounding impact of pollution on our results is technically difficult since pollution and human activity are strongly correlated. Therefore, controlling for pollution in the dataset would implicitly control for human activity. In fact, the results for of Appendix B.2 for precipitations are enough to ensure that our impacts for temperature are not confounded by air pollution. This is since days with rain are significantly less polluted than days without rain.[32]

Minimum versus maximum temperatures. In Appendix B.3, we report the results obtained when running models that jointly use daily minimum and daily maximum temperatures, instead of the daily average temperature. The idea is to disentangle the effect of temperatures at night (given by the minimum temperature) from the effect of temperatures during the day (more consistently captured by maximum temperature). We find that maximum temperatures have a much stronger influence than minimum temperatures on the crime rate. According to our calculations, around 9% of weather-induced crimes correlate with night temperatures. This

[32] In Mexico City, pollution is monitored for several pollutants and daily information on air quality is directly accessible from the Direccion de Monitoreo Atmosferico, and synthesized by an air quality index called IMECA (http://www.aire.cdmx.gob.mx/default.php). A low IMECA corresponds to low air pollution, and there is a clear correlation between air pollution and precipitations: 7.2% of days without precipitation have very poor air quality with an IMECA above 200, against 1.6% of days with precipitation; on the opposite, only 9.1% of days without precipitation have an IMECA below 100, against 27.9% of days with precipitation. Therefore, controlling for precipitations is equivalent to controlling for significant variation in pollution levels. Since results barely change when accounting for precipitation levels, we can be sure than the impacts for temperature are not driven by pollution.

small figure is in fact aligned with the number of crimes committed during the night. For comparison, in the 2016 National Survey on Victimization and Perception about Public Safety, only around 13% of crimes were committed between midnight and 6am.

We have performed the same type of analysis by type of crimes and found no significant difference between the main results and most crime categories. Two exceptions are worth mentioning: rapes and sexual aggressions; and drug-related offenses. We find that minimum and maximum temperatures influence sexual crime rates more evenly. The results in Appendix B.3 suggest that around 35% of weather-related rapes and sexual aggression are induced by minimum temperatures (i.e. happen at night). We can conclude, quite reasonably, that night social contexts matter to sexual crimes. In the case of drug-related violence, we find a strong impact of minimum temperatures below 0°C on the crime rate. However, this strong impact is not immediate, but observable after a few weeks with a distributed lag model. This delayed effect can be explained by the fact that Mexico is a drug-producing country. Minimal temperatures below 0°C may hinder the growth of marihuana and opium, leading to lower levels of drug-related crimes in the medium run.

Acclimation. In Appendix B.4, we used temperatures bins calculated as a deviation from the local average temperature in each municipality, to test for the effect of acclimation on the impacts. Results with relative temperature bins show a similar linear increase in criminality. However, the impact is in fact smaller in magnitude and results are less efficient. The attenuated impacts and efficiency loss make us think that absolute temperatures are a better reflection of true impacts. We also looked at consecutively unusual hot and cold days (i.e. heat and cold waves) and found no additional effect of consecutive days on either increasing or attenuating the general effects found for the lowest and higher temperature bins in the distributed lag model.[33]

Heterogeneity in the sample. In Appendix B.5, we assess if the temperature-crime relationship is different across four climate regions. In all regions, we find that an increase in temperature correlates with an increase in criminality. However, results lose precision at the extremes, and are not conclusive for cold regions, because only a few mountainous areas classify as cold. In Appendix B.6, we divided our sample in two equal periods: 1997-2004 and 2005-2012. Results for 1997-2004 are similar to the ones for 2005-2012 in the contemporaneous model, suggesting

[33] Since they provide not additional insight and for the sake of concision, the results with consecutively hot and cold days are not reported.

no change between the two periods. The results of the distributed lag model have lost efficiency and significance for 1997-2004 while they are clear for 2005-2012. In Appendix B.7, we have run the distributed lag model separately for municipalities with less and with more than 10,000 inhabitants. We find that a clear relationship only for municipalities with more than 10,000 inhabitants. For municipalities below 10,000 inhabitants, the relationship is very imprecisely estimated. However, there seems to be a similar correlation between temperature and crime in small municipalities when we look at the results of the contemporaneous model.

Model choice. In complement, we checked if our results were robust to changes in the structure imposed on the fixed effects. Details are in Appendix B.8. Instead of a fully interacted structure with municipality by month of the year fixed effects, we ran three alternative models: 1) with municipality by year fixed effects and separate month fixed effects; 2) with municipality by month fixed effects and separate year fixed effects; and 3) with separate municipality fixed effects, year fixed effects and month fixed effects. Results are similar.

V.B. Analysis with disaggregated data

In the baseline models, we aggregated the individual crime data at municipality level to construct crime rates. This is because we wanted to quantify changes in crime rates as a function of temperature. Below, we rely on an alternative econometric strategy that directly uses the individual crime data (each observation is a different crime) to look at the correlation between crime characteristics and temperature. Conditional on crimes happening, the econometric strategy below looks at the correlation between temperature bins and the circumstances of crimes. The advantage of this strategy is that it increases precision to look at the correlation between crime characteristics and temperature. As such, we can provide additional insight for a few crime characteristics. We can furthermore look at the identity of weather-related offenders. However, the strategy does not allow us to compute changes in the total amount of crimes. We use the following specification:

(3) $$C_{r,i,d,m,t} = \vartheta . T_{i,d,m,t} + u_{i,m,t} + e_{r,i,d,m,t}$$

$C_{n,i,d,m,t}$ stands for the value of characteristic C for the n^{th} crime committed in municipality i, on day d, month m and year t. $T_{i,d,m,t}$ is the same vector of climate characteristics used for equation (1), $u_{i,m,t}$ is a municipality by month of the year fixed effect and $e_{r,i,d,m,t}$ the error term. The coefficients of interest are represented by vector ϑ. We have ran equation (3) for several sets of characteristics.

Confirmation of previous findings. First, we confirm that drunk offenders more commonly perform weather-related crimes (see Appendix C.1). We furthermore confirm that deterrence is not impaired during hot days (see Appendix C.2). We find that the share of people convicted over the share of people prosecuted is generally not a function of temperature.[34] We also show that there is no difference in the celerity of judgements between hot and cold days: the time gap between criminal acts and judgements does not depend on the temperature on the day of the crime.

Accidents. Another interpretation for an increase in amount of crimes is that accidents are more frequent during hot days. We find that the proportion of unintentional crimes, as classified by the police, is stable across cold and hot days, at around 10% of crimes. Therefore, temperatures appear to have little influence on intentionality (see Appendix C.3).

Failed attempts. We find that criminals are more successful at committing crimes during cold days than they are during hot days: failed attempts are 10-15% more common during a hot day above 32°C than they are during a cold day (see Appendix C.4). This finding is not surprising considering that a larger share of criminals is intoxicated. On the opposite, this is evidence that heat-related criminality does not occur because it would be easier to commit a crime during a hot day.

Weather-related criminals. We look at the age, gender, profession, educational attainment and marital status of weather-related criminals (see Appendix C.5). We find a correlation between the profession of criminals and outdoor temperatures. An interesting feature is that there is no correlation between temperature and the proportion of criminals working in agriculture. This suggests that the time spent outdoors at work does not explain weather-induced criminal activities. This element is not consistent with a physiological explanation for the link between temperature and criminality. We also find that people working in industry are more likely to commit crimes during hot days, whereas people working in administrative jobs, or executives and liberal professions are less likely to do so. In parallel, we find a slightly lower proportion of women offenders during hot days, which is coherent since we found a higher proportion of

[34] Using the data on prosecutions, we use a dummy equal to 1 if offenders are found guilty during their trial and run a regression based on equation (3). We find no correlation between final decisions and temperature, except for days above 32°C. For these days, we find a statistically significant but small increase in the proportion of guilty offenders (by 0.9 percentage points at 5%). However, this effect is likely to be spurious correlation: a joint test of significance for all temperature bins cannot discard the hypothesis that all coefficients are null (p-value of Wald test is 0.16). In general, these results confirm that deterrence is not particularly impaired during hot days. If anything, offenders might be more likely to be found guilty on hot days above 32°C (this is higher deterrence, not lower deterrence).

sexual crimes (>99% are committed by men). We find no correlation between the marital status of offenders and temperature, and slight differences in age and educational attainment but they are not economically meaningful.

V.C. Comparison with other studies

Many of the results presented above are in line with prior evidence provided in related studies. This suggests that the set of mechanisms that we described and linked to existing theories of crime could be found in other countries and using different experimental settings.

Ranson (2014) performs a similar analysis of the impact of temperatures on criminality in the U.S, and then estimate the impact that climate change could have on criminality. In Appendix D, we reproduce an assessment of climate change impacts. Our general estimate is that criminality will increase by 3.3% at the end of the century under the RCP4.5 scenario of medium to high emissions. It lies in the same order of magnitude as Ranson (2014).[35]

The study by Baysan *et al.* (2015) is more closely related to ours since it also relies on Mexican data. Baysan *et al.* (2015) finds that a one standard deviation increase in temperature is associated with a 23% increase in drug-related killings, a 5% increase in "normal" homicides, and a 7% increase in suicides. The work in Baysan *et al.* (2015) suggests that all three types of violent deaths seem to be triggered by a similar underlying pattern. Yet, they find a small impact of economic factors on drug-related killings. Our main results complement their analysis in an interesting fashion. Whereas we find a strong impact of on-the-day temperatures on homicides, this impact produces no additional effect in our distributed lag model. Our climate change estimates for homicides drop from a 1% increase (with 654 murders per year) with on-the-day correlations to a non-statistically significant 0.3% increase (with 202 murders per year) when we use a distributed lag model.

To our understanding, Baysan *et al.* (2015) could be capturing longer term trends and not a short term physiological response to high temperatures. This could be due to the important methodological differences between Baysan *et al.* (2015) and our work. Baysan *et al.* (2015) correlate monthly statistics on killings from drug trafficking organisations, homicides and

[35] Yet, the distribution of impacts across crime categories is different. We find no impact on murders when Ranson (2014) predicts that climate change will increase the number of murders by 2.2%. We predict a very strong impact on rapes and sexual aggressions (10.6% increase), whereas Ranson (2014) finds a milder effect (3.1% increase). Differences in results could be due to the fact that both countries display radically different criminological patterns. Furthermore, Mexico and the U.S. are not exposed to the same temperature range. The impact of temperatures on a few crime categories appears to be non-linear in Ranson (1994) suggesting that a 1°C temperature increase could produce radically different effects in the U.S. and Mexico.

suicides at the state level with weather data for Mexico over the period 1990-2010. Therefore, they use more aggregated data and less powerful controls for seasonality and displacement effects. Moreover, they consider long-run impacts over 6 months whereas we focus on short-run effects over a maximum of 21 days. As for drug trafficking, we find a persisting impact of temperatures on drug-related criminality. Yet, we find a statistically significant effect of cold temperatures – not hot temperatures – in reducing drug-related crimes. The two categories (killings associated with drug trafficking and drug-related crimes) do not match, therefore the results of Baysan *et al.* (2015) and ours are not necessarily contradictory. However, it is still interesting to notice that the effect of cold, not heat, seem to be at play in our data, suggesting that temperatures may affect drug-related activities (including killings) in several, complex ways. For example, we find that low temperatures below 0°C substantially reduce the number of drug-related offenses in the short run. We think this may be due to a reduction in marihuana and opium crop yields. This is consistent with the result of Baysan *et al.* (2015) that drug-related killings could be weakly explained by economic factors.

It is particularly interesting to compare our results with those in Fields (1992) for the U.K. Fields (1992) finds that a 1-standard deviation from the seasonal norm in temperature causes an increase in criminality rates of around 1% (and 1.5% for sexual offenses). Fields (1992) concludes that this increase is caused by a change in activities of U.K. residents on hot days. With our data, a 1-standard deviation from seasonal norms would correspond to an increase in the all-cause accusation rate by around 1.5% (4.8% for sexual offenses).[36] Therefore, the figures in the case of Mexico as higher but comparable to the U.K. evidence. This suggests that similar underlying factors could explain the temperature-crime relationship. Yet, Mexico is very hot whereas U.K. temperatures are almost never above 25°C (even in the South).

McCord, Garg and Monfort (2018) find a linear relationship between on-the-day temperature and homicides rates in Mexico, with similar levels of magnitude as ours. Unfortunately, these authors do not use a distributed lag model and therefore do not account for displacement effects in their main specification. In the case of Mexico, we found strong displacement effects. These effects have also been found with the same order of magnitude by Jacob, Lefgren and Moretti (2007) in the U.S. which suggests that similar mechanisms are at play in Mexico and in the

[36] We found a 3.3% increase in the accusation rate with the RCP4.5 scenario and the distributed lag model. This scenario corresponds to a 3.5°C increase. We can rescale this figure to a 1-standard deviation from the monthly temperature average: this is a deviation of around 1.6°C. For a 1.6°C temperature increase, and using a simple rule of them, we have an increase in the accusation rate by about 1.5% (4.8% of sexual offenses).

U.S., in particular regarding the impact of changes in marginal utility on short-term criminality rates. Whereas Jacob, Lefgren and Moretti (2007) argue that displacement effects are due to decreasing marginal utility, these effects do not specifically identify the impact of changes in marginal benefits on criminality. Criminals could rationally time their offenses to take advantage of good climatic conditions. A contribution of our research is to analyse the role played by impunity and opportunities in driving the correlation between temperature and crime, and to corroborate that decreasing returns constitute the main factor driving displacement effects in crime rates.

VI. Conclusion

The correlation between temperature and crime has been observed across all types of climates. Past research has often interpreted this phenomenon as the expression of a biological link between temperature and aggressiveness. Yet, the medical evidence is scarce, and the literature in experimental psychology has relied on small samples and on settings that are not able to reproduce the circumstances of criminal offenses in a reliable way.

In this paper, we find that an increase by one degree Celsius increases the accusation rate of all types of crimes by 1.3%. The effect is linear, which casts doubt on the fitness of a purely metabolic explanation for the temperature crime-relationship. On the opposite, we find that alcohol consumption and time use during weekends have a direct influence on the crime-temperature relationship. We wonder why time use and alcohol matter so much. We find that, in 40% of cases, crime peaks during hot days are compensated by lower rates on the following days. The crime-temperature relationship is therefore split between additional crimes and displaced crimes. The displaced crimes suggest that social interactions intensify during warmer days, but that some criminals acts are not committed again following hot days because of decreasing returns to crime. The full displacement of homicides in our data exemplifies this element – there is no value in trying to kill the same person twice. For additional crimes, temperature must strongly influence the underlying utility function commanding crime. We find no evidence that hot days provide better opportunities. On the opposite, failed criminal attempts are more frequent on warmer days. We also find no evidence that sanctions are less likely (or more likely to be delayed) if a crime is committed during a hot day. By process of elimination, we conclude that the perceived benefits from committing some crimes during hot days may be magnified by social activities that correlate with hot temperatures. This aligns with modern psychology that suggests that criminal behaviour is learnt during childhood and adolescence, and heavily relies on anti-social peer associations.

Taken globally, our findings have implications beyond heat-induced criminal events. Crime seems particularly sensitive to immediate rewards or their perception, which may be altered by the social context (e.g. in antisocial group associations or because of substance use). As such, social and health policies (e.g. that would tackle drug addiction) could be suited to deal with the type of criminality that our analyses uncover. Our findings appeal for dedicating more funding and research on programmes targeting the social environment of offenders, in particular substance use and anti-social peer associations.

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Tables

Table 1: Average daily accusation and prosecution rates by type of crime and circumstance (in accusations per million inhabitants, 1997-2012)

Type of crime	Daily accusation rate	Daily prosecution rate
All crimes	5.78	4.07
Homicide	0.20	0.16
Injury	0.85	0.55
Rape and sexual aggression	0.16	0.12
Possession of weapons	0.42	0.35
Property damage	0.48	0.28
Drug-related crime	0.38	0.28
Theft (excl. car theft)	1.68	1.34
Car theft	0.03	0.03
Manslaughter	0.01	0.01
Kidnapping	0.03	0.02
Unintentional	0.54	0.36
Intentional	5.16	3.66
Premeditated	0.013	0.004
Weekdays	5.64	3.98
Weekends	6.14	4.29
Found guilty	-	3.57
Found not guilty	-	0.48

Notes: The accusation rates correspond to the average daily accusation and prosecution rates per million inhabitant at municipality level. Rates are weighted by the population in each municipality. These figures are averages based on the dataset finally used for the regressions. They therefore exclude observations for which weather data was missing. Note that, for some crimes, we do not have information on intentionality or crime resolution, explaining why the total of crimes by intentionality or guilt does not match the national average.

Figures

Figure 1: Average daily accusation rate by municipality (in accusations per million inhabitants, 1997-2012)

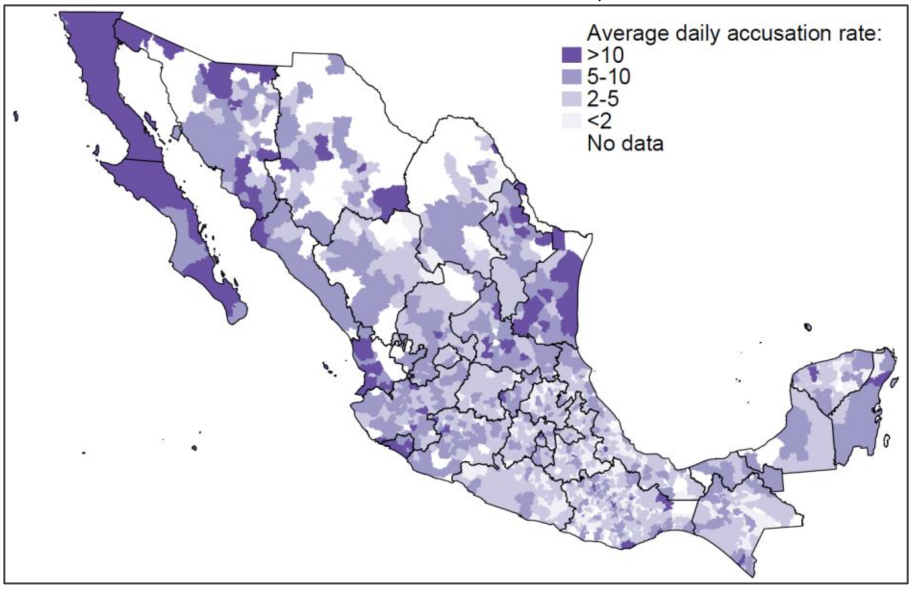
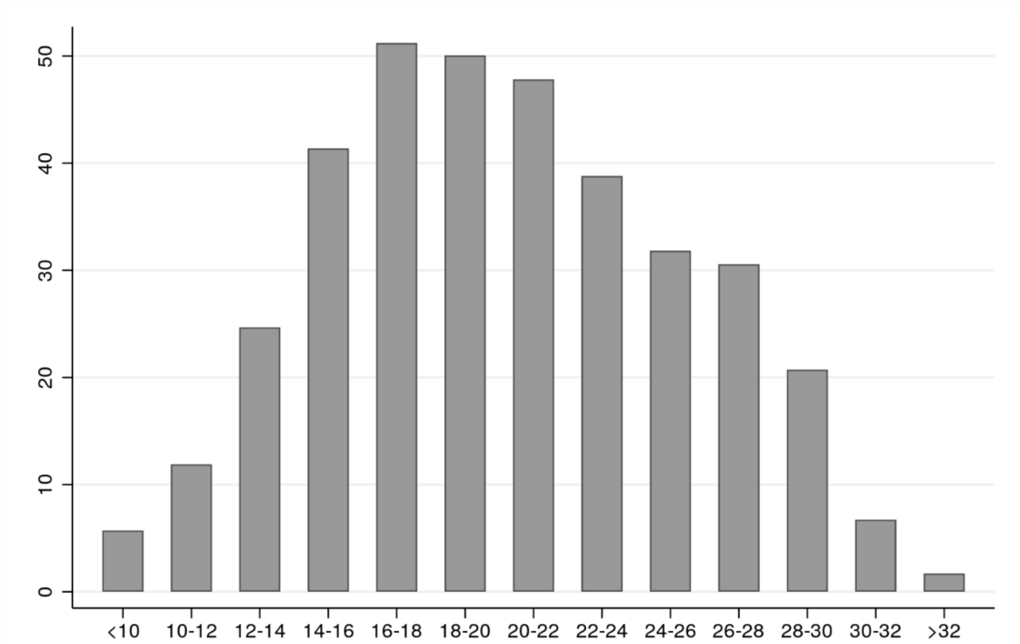
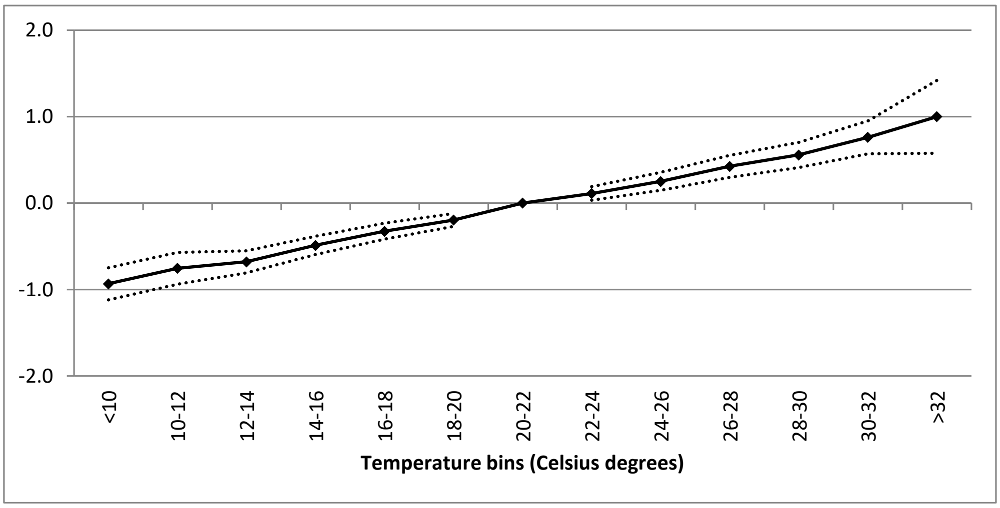


Figure 2: Distribution of hot and cold days in Mexico across 13 temperature bins (in °C) (1997-2012)



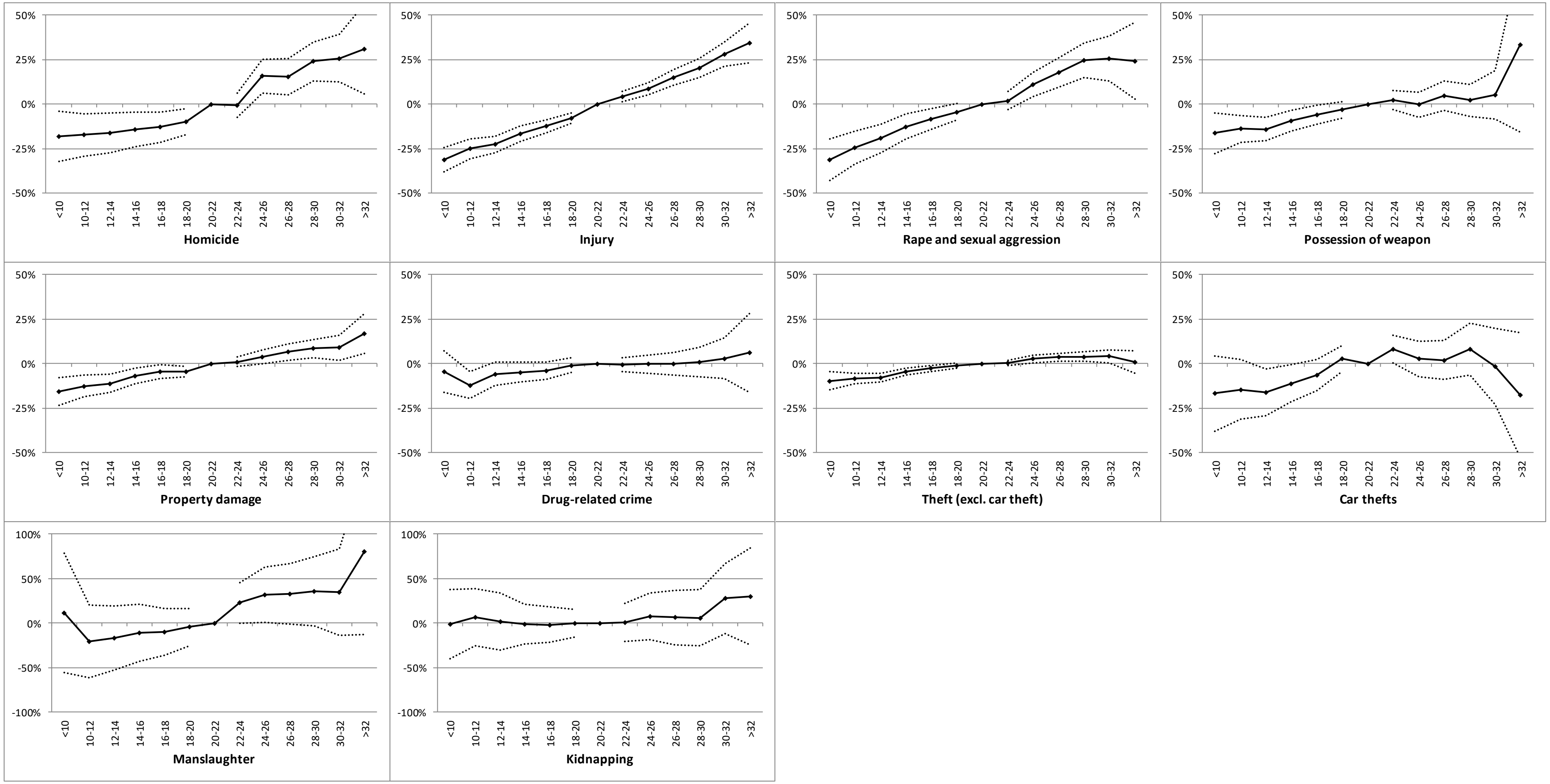
Notes: The Figure shows the distribution of daily average temperatures in Mexico across 13 temperature-day bins, expressed in Celsius degrees. The y-axis corresponds to the average annual number of days in each bin, over 1997-2012.

Figure 3: correlation between on-the-day temperature and accusations (all types of crimes)



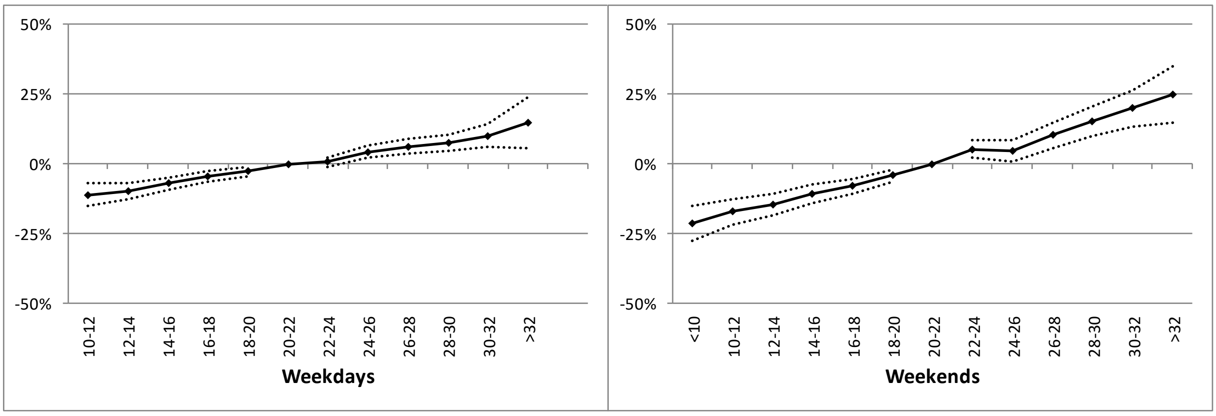
Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The regression also includes municipality by-month by-year fixed effects and is weighted by the square root of the population in each municipality. 95% confidence intervals are in indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees. 370,094 groups and 30.1 observations per group.

Figure 4: correlation between on-the-day temperature and daily accusation rates by type of crime



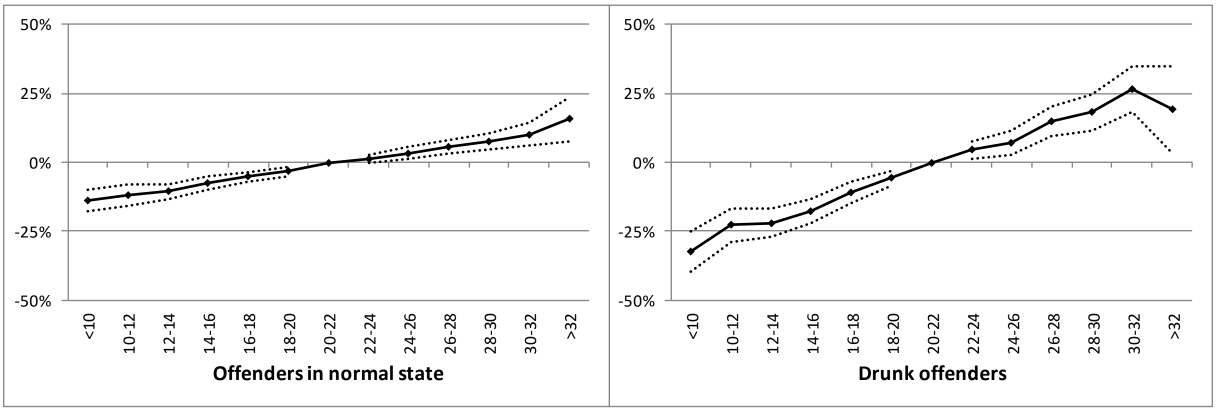
Notes: each graph corresponds to a separate regression. The dependent variable is daily accusation rate as a share of the average accusation rate of each category. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are in indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

Figure 5: Contemporaneous effect of temperatures on the accusation rate during weekdays and weekends



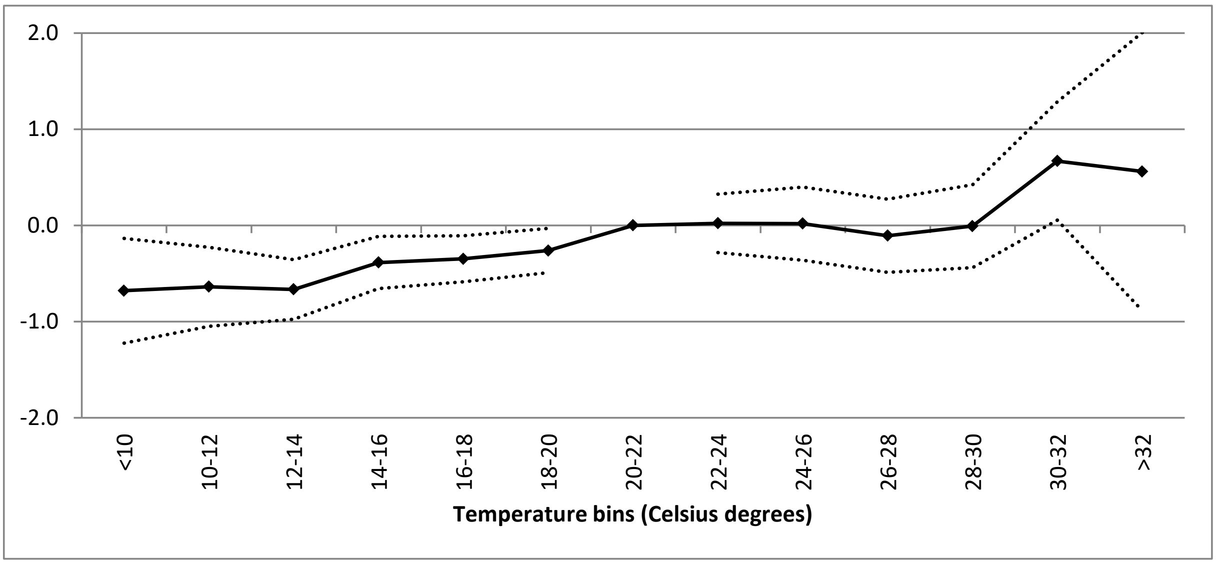
Notes: each graph corresponds to a separate regression. Results are separately displayed for weekdays (left panel) and weekends (right panes). The dependent variable is daily accusation rate as a share of the average accusation rate. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The y-axis reports the contemporaneous effect of temperatures on accusation rates. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are in indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

Figure 6: Contemporaneous effect of temperatures on the accusation rate for offenders in a normal state vs. drunk offenders



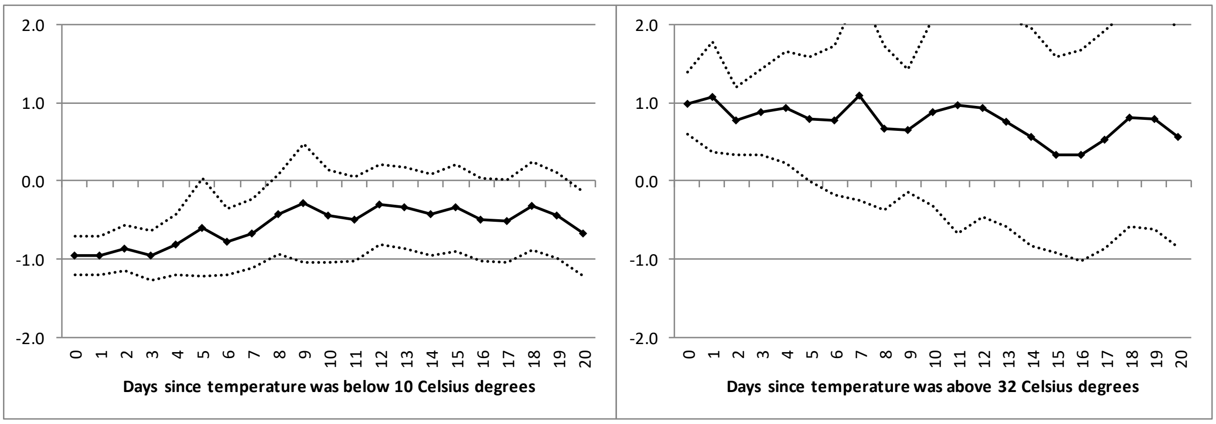
Notes: each graph corresponds to a separate regression The dependent variables are the daily accusation rate for people in a normal state (upper panels) or drunk offenders (middle panels) a share of the average rate of each category. The y-axis reports the contemporaneous effect of temperatures on accusation rates. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. The reference bin is 20-22 Celsius degrees.

Figure 7: 21-day cumulative effect of temperature on accusations (all types of crimes)



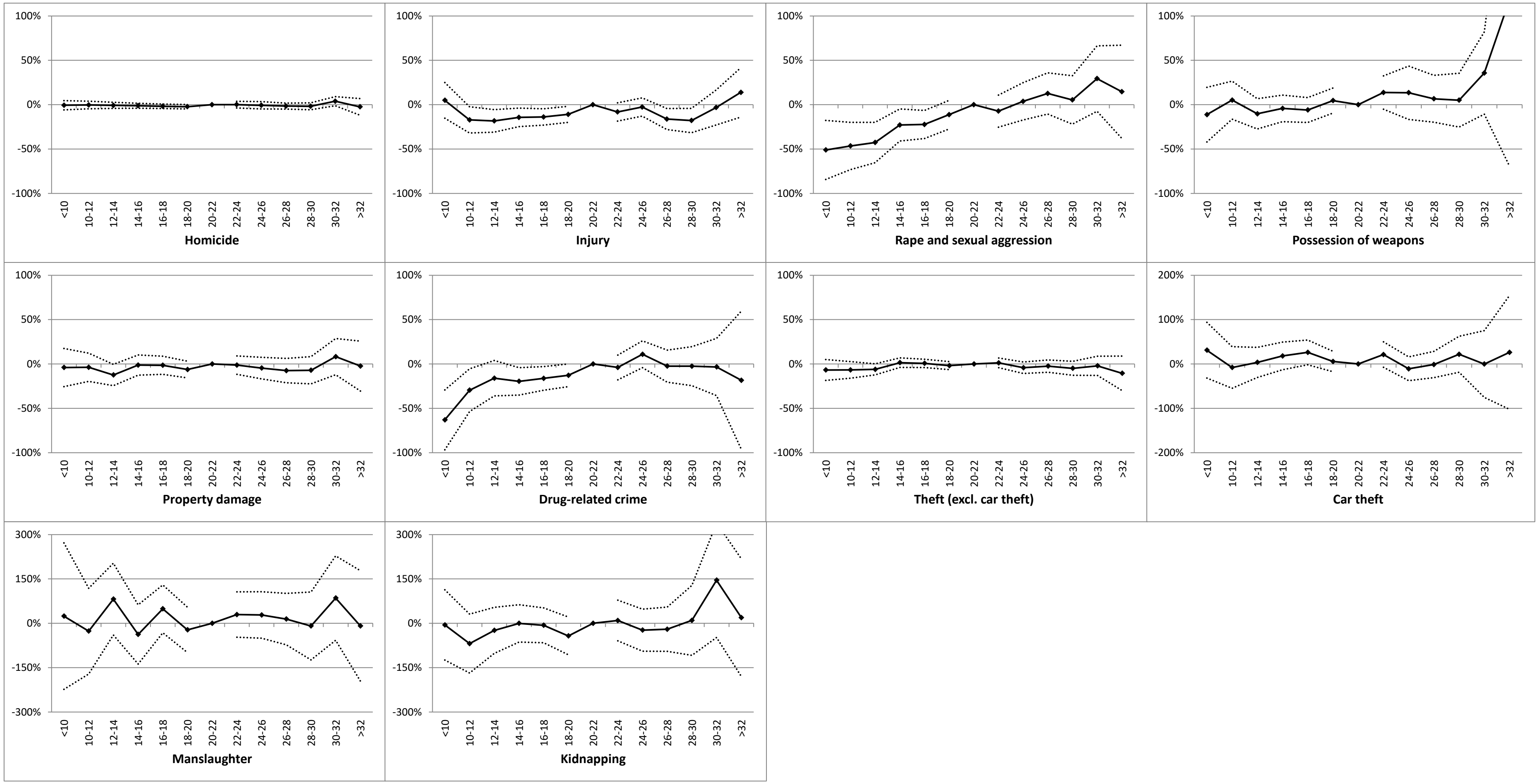
Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The y-axis reports the long-run multiplier of each temperature bin on the accusation rates. The multiplier includes on-the-day temperature and 20 lags. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are in indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees. 370,094 groups and 30.1 observations per group.

Figure 8: Rollout of the cumulative effect of temperature on accusation (all types of crimes) for days below 10 Celsius degrees and above 32 Celsius degrees



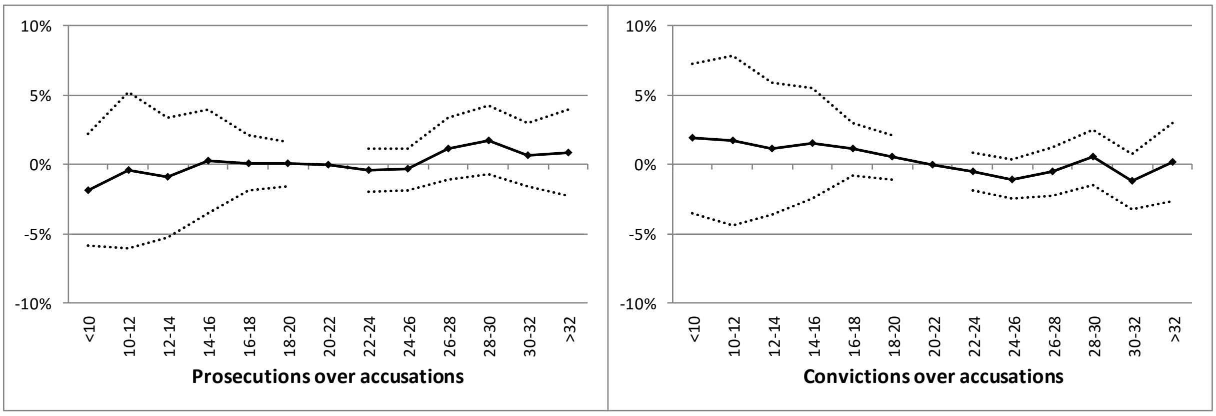
Notes: The information displayed above comes from the same estimation results as for Figure 7. The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The y-axis reports the long-run multiplier of each temperature bin on the accusation rates. The multiplier includes on-the-day temperature and 20 lags. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are in indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees. 370,094 groups and 30.1 observations per group.

Figure 9: 21-day cumulative effect of temperature on daily accusation rates by type of crime



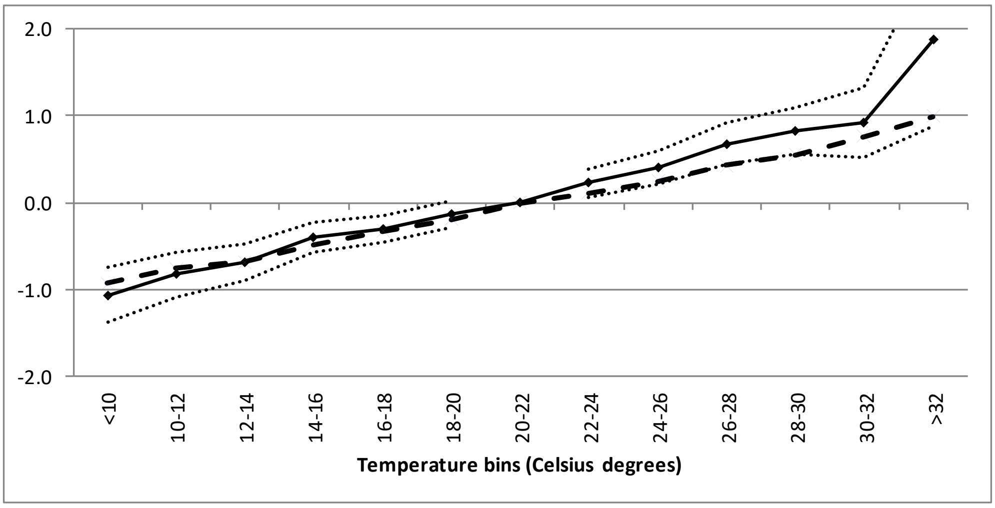
Notes: each graph corresponds to a separate regression. The dependent variable is daily accusation rate as a share of the average accusation rate of each category. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The y-axis reports the long-run multiplier of each temperature bin on the accusation rates. The multiplier includes on-the-day temperature and 20 lags. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are in indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degree.

Figure 10: Contemporaneous effect of temperatures on the proportion of accusations leading to prosecutions and convictions



Notes: each graph corresponds to a separate regression. The dependent variables are the proportion of prosecutions (left panel) and convictions (right panel) over the total number of accusation in municipality *i*, day *d*, month *m* and year *t*. The x-axis corresponds to the temperature bins (in Celsius degrees) and the reference bin is 20-22 Celsius degrees. Regressions are weighted by the average number of prosecutions recorded in municipality *i*, month *m* and year *t*. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. Dashed lines correspond to 95% confidence intervals with cluster-robust standard errors at the level of municipalities.

Figure 11: effect of on-the-day temperature on accusations (all types of crimes), assuming that the following 7 days record the same temperature level



Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The y-axis reports the long-run multiplier of each temperature bin on the accusation rates. The multiplier includes on-the-day temperature and 7 leads. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. The full line corresponds to the point estimates. 95% confidence intervals are in indicated by short dashed lines (for standard errors clustered at the level of municipalities). The point estimates of our baseline results are presented for reference only using long dashes. The reference bin is 20-22 Celsius degrees.

"Temperature and the Allocation of Time: Implications for Climate Change," with Joshua Graff Zivin. Journal of Labor Economics, 32(1), 2014.

Time outside at 25˚F is 37 minutes less than at 76˚F–80˚F, and it steadily climbs until 76˚F–80˚F. It remains fairly stable until 100˚F and falls after that, though the impact at the highest temperature bin is not statistically significant.

Indoor leisure increases by roughly 30 minutes at 25˚F compared to 76˚F–80˚F, and it then steadily decreases until 76˚F–80˚F. It remains stable until roughly 95˚F and then increases considerably after that.

Albouy, D., Graf, W., Kellogg, R., & Wolff, H. (2016). Climate amenities, climate change, and American quality of life. *Journal of the Association of Environmental and Resource Economists*, *3*(1), 205-246.

We find that Americans favor an average daily temperature of 65 degrees Fahrenheit, will pay more on the margin to avoid excess heat than cold, and are not substantially more averse to extremes than to temperatures that are merely uncomfortable