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January 2018

Centre for Climate Change Economics
and Policy Working Paper No. 326
ISSN 2515-5709 (Online)

Grantham Research Institute on
Climate Change and the Environment
Working Paper No. 291
ISSN 2515-5717 (Online)

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Understanding Interpersonal Violence: the Impact of Temperatures in Mexico

This version: January 2018

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Abstract

We estimate the effect of temperature on criminality in Mexico and question conventional wisdom that high temperatures impact human psychology. Using high-frequency data, we find a linear effect of temperatures on criminality, inconsistent with the belief that only high temperatures cause disturbances. A significant share of weather-related crimes can be explained by higher alcohol consumption (9%) and changes in time allocation during weekends (17%). Also, 28% of weather-related crimes are committed at night, when temperatures are mild, and a third is driven by short-term displacements, causing no additional victim.

Keywords: extreme weather events; temperature; criminality; distributed lag model; routine activity.

JEL codes: K42, K49, Q54, Q56.

Acknowledgements: For useful comments, we thank Jennifer Inauen, Claudia Pfeifer Cruz and Emilio Picasso along with participants at AELE 2017, IRMBAM 2017 and the 2017 Oxford economics postdoc seminar series. Cohen acknowledges funding from the ESRC Centre for Climate Change Economics and Policy and the Grantham Foundation for the Protection of the Environment.

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1. Introduction

Increasing safety and reducing violence constitute a priority in Latin America. In the subcontinent, the direct cost of criminality would be equivalent to 3.6% of GDP (Inter-American Development Bank, 2017).¹ Not only populations are victim of drug trafficking and organised crime, they are also vulnerable to small delinquency which often degenerate into injuries, and sometimes murder. Yet, the media and governments, along with U.S. foreign policy, have focused their attention on winning the war against drug traffickers. Increasing the means given to police and the military to fight cartels has not been as successful as expected (e.g. Dobkin et al., 2009, on methamphetamines in the U.S.). It also came at a high operational cost and caused heavy collateral damage. Nowadays, analysts wonder what failed and if health and welfare policies could have done a better job in the fight against crime (Quah et al., 2014).

In this paper, we take a step back and aim to understand the motives behind the bulk of offenses committed in Latin America. We do not want to restrict the analysis to cartel-related or drug-related violence, acknowledging that criminality is a much broader, pervasive problem. The main difficulty to understand the motives of crime is the absence of experimental contexts to assess the relative contribution of different factors that might fuel criminality. To address this concern, we specifically look at surges in violence concomitant to hot days in Mexico. Rises in crime rates occurring because of high temperatures provide us with the context of a natural experiment to assess the reasons behind sudden increases in criminality.

A wide literature has shown that criminality and aggressiveness rise sharply with high temperatures. This phenomenon has been observed in different countries, time periods and social contexts (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). In the data on Mexico used throughout this paper, the crime rate is around 80% higher during hot days above 32°C than for any other day.

Yet, observers have not been able to agree on the reasons behind the short-term correlation between criminality and hot days. A very important question is whether temperatures have an impact on criminals or on their environment. A psychological explanation suggests that short-

¹ This is \$261 billion annually, and as much as the annual income of the 30% poorest population on the subcontinent, underpinning the consequences that crime has for development. Impacts are not evenly spread across countries (or regions within countries). In El Salvador and Honduras, the direct cost of crime would be above 7% of national GDP, while it is much lower in safer countries, e.g. Chile.

term exposure to higher temperatures increases the likelihood of aggressive behaviour because of underlying physiological factors. That is, high temperatures could alter human perceptions or preferences for aggressive behaviour (Anderson, 2001). However, this physiological explanation cannot rule out the perspective that criminal acts are utility-maximising for self-interested actors. Following the tradition of Becker (1968), the opportunity channel sets forth that, if temperatures alter the probability of success of a criminal offense or reduce the probability or severity of punishment if caught, the correlation between temperature and criminality could be the reflection of a calculation from offenders in a changing environment. There is also a behavioural interpretation of the impact of temperatures on criminality. Potential victims and offenders may modify their everyday activities when confronted to a change in temperature. Victims may prefer outdoor leisure activities when the weather permits, potential offenders may participate in gatherings or be more likely to consume drugs or alcohol. The social interaction channel set forth that temperatures change time allocation in a way that puts offenders and victims in contact with each other during hot days (Cohen and Felson, 1979).

We use daily crime records for Mexico on accusations and processed individuals from the “First Instance Courts” from 1997 to 2012 to assess the likely contribution of these channels to the association between weather and crime. To the best of our knowledge, the attempt of this paper is unique in the literature. We are not aware of any other paper that used exogenous environmental shocks to analyse the fitness of a range of theories of crime to national-level data.

Studying the correlation between criminality and temperature in Mexico offers additional advantages. Mexico is a country with high criminality levels, displaying very diverse criminal profiles, from every day delinquency to organised drug trafficking. It is also one of the hottest countries in the world: the effect of high temperatures on criminality should be visible and possibly triggered by a wide set of reasons. Finally, comparing the results obtained for Mexico with the ones obtained in other studies for the U.S. (e.g. Ranson, 2014) may allow us to identify some of the specificities of the temperature-criminality relationship in an emerging economy, furthermore victim of drug trafficking and cartels.

We combined our crime dataset with daily temperature and rainfall data from the Mexican National Weather Service. Our merged dataset covers 90% of Mexican municipalities for 16 years and consists of about 12 million daily crime rates at the municipality level. We use two different types of econometric specifications. First, we use a model of contemporaneous effects that correlates daily criminality rates with local daily temperatures. 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. Second, we use a distributed lag models to account for displacement effects. This additional approach allows us to assess if sudden increases in crime rates are offset by lower crime rates in the following days or followed by retaliations. Methodologically, it is the first time that such an approach is used on daily data to look at the short-term dynamics of the correlation between temperature and all sorts of crimes.

We find an almost linear and positive contemporaneous relationship between temperature and criminal activity. An increase of one degree Celsius increases the accusation rate of all types of crimes by 1.3%. The crime accusation rate is expected to be one third higher during a hot day ($>32^{\circ}\text{C}$) than during a cold day ($<10^{\circ}\text{C}$). These results on the contemporaneous correlation between criminality and temperature are consistent with previous research (Ranson, 2014; Horrocks and Menclova, 2011). The results of the distributed lag model indicate, however, that 35% of the peaks in criminality rates occurring during hot days are compensated by reductions in criminality levels during the following days. This is in line with the results obtained by Jacob, Lefgren and Moretti (2007) for the U.S.

We also disaggregate our results by type of crimes. In the contemporaneous effects model, we find a strong effect of higher temperature on a series of violent crimes: homicides, injuries, rapes and sexual aggressions, and possessions of weapon. We find a small effect on property damage, thefts and drug-related crimes. In the distributed lag model, the effect of temperature on criminality rates is no longer visible for most types of crimes. This indicates that displacement effects may offset most of the immediate correlation between violent crimes and temperature. However, we find a long-lasting effect of temperatures on accusations of rapes and sexual aggression, and on accusations of drug-related crimes. Further analyses suggest that the effect on drug-related accusations may mostly be due to a reduction in the production of drugs when temperatures reach low levels (e.g. $<0^{\circ}\text{C}$). We also find that the additional and long-lasting effect on accusations of rapes and sexual aggression is mostly due to lower rates during colder days. All these results are not confounded by the impact of precipitations on crime, which is found to be much milder than the impact of temperatures.

The magnitude of these results can be assessed with regards to future climate change impacts. We use the RCP4.5 intermediate scenario to project future temperatures changes in Mexico and find that crime accusation rates would increase by 4.3% and 3.3% in the contemporaneous and the distributed lag model, respectively, at the end of this century. The distributive lag model

predicts an increase by 10.6% of the amount of accusation rates for rapes and sexual aggressions under climate change by 2100.²

The main contribution of this paper is the observation that these statistical results are not fully compatible with a psychological interpretation of the impact of temperature on criminality. First, criminality levels are almost linear in temperature, whereas either a psychological or physiological effect should be non-linear, e.g. with no effect within the comfort zone of the human body (20-25°C) thanks to thermoregulation, and sharp effects at the extremes. Second, we find strong transitional effects that imply that some of the correlation between temperatures and crimes may be caused changes in deterrence levels or the displacement of everyday activities according to weather conditions. Finally, we find an impact of colder temperatures on rapes. This phenomenon does not fit with standard psychological explanations. It does not fit either with an income-based explanation considering the non-financial nature of rapes and sexual abuses.

In the second part of the paper, we assess the fitness of rational and behavioural theories of crime to the statistical evidence available to us. To do so, we explore the circumstances of weather-induced crimes. We first check if weather-induced crimes are committed intentionally. We find that both intentional and unintentional crimes are committed during hot days, and that the great majority of weather-related crimes (around 90%) are intentional. Then, we assess if it is easier to commit a crime during a hot day. However, we observe no change in impunity levels between cold and hot days: the proportions of accused people that are finally convicted are the same during cold and hot days. On the opposite, several elements corroborate the idea that populations adapt their activities to the weather, which might in turn increment victimisation risk. In particular, we uncover that 9% of weather-related crimes committed are in fact crimes triggered by an additional use of alcohol determined by weather conditions. Furthermore, hot temperatures have a statistically stronger impact on criminality during weekends than during weekdays. Changes in time allocation during weekends (as compared to weekdays) are found to be responsible for 17% of all weather-related crimes. We also found that 28% of heat-related

² The perspective that global warming might not be contained to a 2°C increase has motivated a new strand of economic literature devoted to studying the possible consequences of climate change. Among other things, a consensus has emerged that climate change may trigger new conflicts, both at intergroup and interpersonal levels (see Burke, Hsiang and Miguel, 2015; Hsiang, Burke and Miguel, 2013; Hsiang, Meng and Cane, 2011 for detailed reviews). Interested in the impact of climate change on droughts and floods, the authors interested in climate change have proposed that, mostly in developing countries, drier and warmer weather can reduce agricultural yields and income, leading to an increase in economically-motivated uprisings and crimes. Our results would complement these, even though they could be driven by different motivations.

crimes may have in fact been committed at night. Rapes and sexual aggressions appeared to be equally sensitive to night and day temperatures, with 39% of weather-induced rapes and sexual aggressions caused at night. This additional set of analyses confirms that the amount of rapes does not seem to be significantly higher during hot days, but significantly lower during cold days instead.

These results have important policy implications. If we focus exclusively on heat-related criminality, policy responses should account for modifications of routine activities and increases in victimisation risk during hot days. On the opposite, we cannot provide conclusive evidence that physiological moderators such as air conditioning, proper hydration or measures aiming at reducing the heat island effect in city centres might constitute an appropriate response to heat-related criminality, as psychologists have often argued. We expect that increased surveillance and prevention policies during hot days could be more effective to cope with heat-related criminality. In particular, since we observe a very strong, persisting impact of temperatures on rapes and sexual aggression, police should increase surveillance activities during hotter days around areas where these crimes have previously taken place. Awareness campaigns about sexual abuses and rapes should also mention hotter weather as a risk factor. However, more research is needed to assess the effectiveness of different measures in reducing heat-related criminality.

More generally, our results are informative about the main drivers of crime outside the boundaries of weather-induced violence. We observe a high response of offenses to changes in circumstances. This supports the view that urban design can significantly lower criminality down, reducing the need for coercive methods. In the fight against drugs, these findings remind us that criminality has many drivers and that increasing dissuasion and repression alone may constitute a suboptimal choice from a policy perspective.

The paper consists of six sections. Section 2 summarizes the existing literature on temperature and crime from a multidisciplinary perspective. Section 3 presents the data on crime accusations, processed individuals and weather in Mexico during our sample period. Section 4 explains our empirical strategy, presents the general results and the results by type of crime. Section 5 analyses the possible channels through which temperature may affect crime accusations. Finally, Section 6 provides concluding remarks.

2. 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 1,980 to 2,009. 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 crimes under climate change in the U.S.

2.1. A higher taste for violence

The existence of a temperature–aggression relationship in many contexts has conducted researchers to think that high temperatures might consistently impact human behaviour. In particular, this gave rise to psychological explanations focusing on the link between temperature and aggression. For example, 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. In 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 psychological theoretical frameworks on the temperature–aggression relationship revolve around the notion of “crankiness” (Anderson, 2001). High temperatures produce lack of comfort and this would affect the way people perceive things.³ For example, minor insults

³ The notion of crankiness is compatible with several theories of social behaviour. For example, Berkowitz's (1984) cognitive neo-association theory suggests that the people that are repeatedly exposed to aggression develop networks of aggressive thoughts. These networks would be more easily triggered by external factors, such as

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.

Yet, the psychological 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. Above all, 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 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.⁴ However, the scientific evidence on the physiological determinants of aggression does not allow making definitive conclusions. The neurobiological mechanisms that determine aggressive behaviour are not yet fully understood, let alone their possible interaction with

violent media or, eventually, uncomfortable temperatures. Likewise, Zillmann's (1971) excitation transfer theory also suggests that high temperatures could increase violence. In this framework, uncomfortably hot temperatures produce negative affect. This affect may be transferred to an external object. In the end, the negative affect produced by hot temperatures is misattributed to the foreign object (Anderson, 2001). Another psychological theory that could explain the impact of hot temperatures on aggressive behaviour is the negative-affect escape model (Anderson, 1989; Anderson et al, 2000; Bell and Baron, 1976). In this model, hot temperatures should increase violence when subjects are exposed to moderate levels of negative affect. However, as soon as the amount of negative affect becomes overwhelming, temperature may increase escape strategies and therefore reduce violence. Anderson (2001) conducts a meta-analysis and finds that there is supportive evidence of a linearly positive effect of heat on aggression, but finds little support for any decrease in aggression levels when additional negative affect-producing factors are present in conjunction with heat (Anderson et al., 2000).

⁴ Anderson, Anderson and Deuser (1996) identify three separate channels through which temperature could impact aggressiveness: the affective route (the development of negative feelings), the cognitive route (the development of aggressive thoughts) and the arousal route (physiological responses such as increases in heart rates). They test for the impact of both cold and hot temperatures, as well as the impact conveyed by images of guns, on the first two of these routes in lab experiments. Both cold and heat contribute to the development of negative feelings, consistently with the psychological theory that temperature creates some level of discomfort which may translate into aggressiveness. On the opposite, they find no impact of temperatures on the cognitive route, which is nonetheless activated by the display of images of weapons. The authors finally suggest that high temperatures could have a positive impact on the arousal route whereas cold temperatures could reduce arousal. They do not test for this last element, namely the difference in the physiological response to heat and cold, but this is an alternative explanation about why cold and heat have asymmetric effects on violent behaviour.

environmental factors such as ambient temperatures.⁵ Up until now, the social impact of hormonal concentrations has been analyzed by social scientists in a series of circumstances. Sherman et al. (2016) find that individuals with both high testosterone and low cortisol are more likely to occupy high-status positions in social hierarchies. The anti-social behavior of delinquents, young offenders and disruptive children has also been explained by hormonal factors in recent research (e.g. Popma et al. 2007; Banks and Dabbs, 1996; Scerbo and Kolko, 1994; Dabbs, Jurkovic and Frady, 1991). However, it is difficult to conclude that these studies necessarily capture the causal effect of hormonal differences on aggression. Testosterone, a hormone of central importance in aggressiveness, is known to respond to external factors. For example, its concentration increases before men engage in competition (e.g. Carré and Olmstead, 2015; Carré et al., 2010; Archer, 2006). The causal impact of testosterone on aggressiveness is not totally clear, since reverse causality is also possible: high levels of testosterone could be the outcome of social interactions, and not their cause.⁶

Another physiological channel through which temperature may affect aggression is through 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). Later on, we explain that criminal offenses are often characterized by suboptimal choices, in particular a wrong assessment of the pros and cons of committing an

⁵ Recent reviews of neuroscience research on anger and aggression (Angus et al., 2016; Montoya et al., 2012) explain that three major hormones influence aggressive behaviour: testosterone, cortisol and serotonin. Researchers have observed a mutually antagonistic effect of testosterone and cortisol on aggressive behaviour (van Honk et al., 2010). An imbalance in the two hormones, characterised by relatively high levels of testosterone and low levels of cortisol, create the ideal hormonal cocktail for aggressiveness in humans. Since testosterone is present in significantly higher amounts among men, differences in aggressiveness between men and women find a biological root. In addition, cortisol and serotonin interact in a complex manner. High cortisol seems to augment the inhibitory effect of serotonin on aggression (Summers and Winberg, 2006; Summers et al., 2005). In fact, much of the neurocircuitry for stress and aggression overlaps. The neurotransmitter serotonin (5-HT) responds rapidly to stress, and also appears to play an important role in the inhibitory regulation of aggressive behaviour. In general, biological factors associated with the production, transportation or reception of serotonin might lead to aggressive or antisocial behaviour. For example, low levels of cholesterol have been found among the authors of violent aggressions (Repo-Tiihonen et al., 2002). Cholesterol is known to play a role in the transportation and reception of serotonin, in particular in relation to 5-HT receptors (Pucadyil et al., 2004), as well as in the reception of gamma-aminobutyric acid (GABA), a substance which intervenes in the neuronal circuits associated with the regulation of behaviour (Brot et al., 1997; Alvarez et al. 1999). Likewise, low levels of the alpha-amino-acid tryptophan, a primary component for the synthesis of serotonin, have been found in antisocial subjects (Swann, 1999). Neuronal circuits also play an important function in the regulation of aggressiveness: several neuropeptides seem to be also involved in the expression of aggressive behaviour. In rats, the V1b receptor of arginin-vasopressin has been found to play an important role in triggering aggressive behaviour (Blanchard, 2005).

⁶ Mazur and Booth (1998) show that testosterone levels of the same individuals before marriage, during marriage and after divorce are radically different. When single, men display higher testosterone levels. Mazur and Booth (1998) hypothesize that single men are more likely than married men to face confrontations and challenges while lacking the social support of a spouse. The risks of frequent confrontations could impact testosterone synthesis in specific moments of their lives.

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.

As for now, we have only considered a psychological or physiological route for the immediate impact of temperatures on criminality. The central idea would be that temperature affects aggressiveness. More violent crimes should therefore be expected during hot days. However, criminality is a complex phenomenon. We now turn to presenting other explanations of the correlation between temperature and crime that do not rely on an inward-looking interpretation of the relationship between temperature and crime. On the opposite, they mostly consider that the environment within which criminals evolve may be affected by temperatures.

2.2. Higher marginal utility

There is a risk that temperatures influence the value of committing a crime, especially since weather conditions could produce negative income shocks and subsequently trigger economically motivated crimes. This phenomenon may produce any sort of crime, either violent or non-violent, provided that there is an economic motivation to the crime.

In the medium to long run, economic studies have shown that several types of violent and non-violent crimes are more likely to take place during floods or droughts in economies that are dependent on agriculture (Blakeslee and Fishman, 2015; Iyer and Topalova, 2014; Miguel; 2005). This phenomenon has also been observed in 19th-century Bavaria (Mehlum, Miguel and Torvik, 2006) and during the Mexican revolution (Dell, 2012).⁷

In the short-run, economically motivated crimes are unlikely to be triggered by hot days. However, short-run dynamics may influence the timing of crimes. Jacob, Lefgren and Moretti (2007) use a panel of weekly crime data for 116 jurisdictions in the U.S. from 1995 to 2011. They aim is to assess if crime in one week is followed by more criminal in the following weeks (due to imitation and retaliation) or, on the opposite, by less crime in the following weeks (due to a marginal decrease in the value of committing additional criminal acts). Jacob, Lefgren and Moretti (2007) find that 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

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, 2015 and Dell, Jones and Olken, 2014, for a complete review of this literature).

crimes committed during one week. They explain this result by arguing that committing again the same type of crime does not provide the same benefits. On the other side, these authors 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.

2.3. Lower dissuasion

The probability of being caught may be different when an act is perpetrated during a cold day rather than during a hot day. This could modify the amount of crimes committed during hot days if criminals act rationally.

Framing criminal acts as potentially rational has been particularly attractive to economists since the seminal paper by Becker (1968). 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. 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.⁸ In this case, it is a responsibility of criminal law and its enforcement, hand in hand with the general community, to counter any benefit from breaking the law that could rise from rational utility maximisation: to ensure safety, there should be no rational calculation that would make criminal conducts advantageous (Kramer, 1990).

Apart from possible changes in tastes or utility already discussed, hot temperatures might encourage rational criminals to misbehave if crime prevention is impaired during hot days. Currently, we are aware of no study showing that hot temperatures might actually alter the probability of receiving a sanction, even though this eventuality cannot be discarded. Meanwhile, there is some empirical evidence that criminality is responsive to deterrence, even though the response to deterrence would be moderate. The likelihood of being punished has been found to reduce criminality more than any other measure of deterrence, in particular than the severity of the punishment (see Travis *et al.*, 2006, for a literature review and meta-analysis on deterrence).⁹

⁸ In such frameworks, a weakening of social or institutional bonds could also lead to more offenses being committed.

⁹ In deterrence theory, three parameters usually determine the efficiency of deterrence: the certainty, severity and celerity of punishment. There is not much evidence on impact of celerity – the fact that a punishment may be

2.4 Changes in social interactions

Even though a rational channel might explain temperature-driven criminality, one should be careful that the role played by rationality in explaining criminal behaviour is not clearly delineated. The personality traits of criminals typically differ from the ones of non-offenders. They include defiance, hostility, lack of self-control, a weak conscience and an inability to plan for the future or defer gratification.¹⁰ Also, individuals that display criminal attitudes often do so in a time-persistent manner. Finally, some criminals do not seem to act rationally at all (e.g. psychopaths), such that not all crimes may be easily explained with a rational approach.¹¹ At the same time, more research is required on the relationship between rationality, cognition and criminal behaviour.¹²

applied quickly or not – on the amount of criminal offense being committed (Onwudiwe, Odo and Onyeozili, 2005).

¹⁰ 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.

¹¹ The fact that criminals could be acting rationally is a thesis that has been extensively criticised. Hirschi (1986) notes that criminology has long been about identifying the substantial differences between offenders from non-offenders as innate traits coming from biological dysfunctions. In a less deterministic way, anomie theories of crime (e.g. Durkheim, 1893; Merton, 1938) interpret criminality as a (necessary) product of society and pay little attention to the question of individual responsibilities. Shaw and McKay (1942) argue that social disorganisation, i.e. the physical deterioration of urban areas and the absence of community effort to cope with poverty and its associated plagues (e.g. physical and mental illnesses, criminality) explain the rise of juvenile delinquency. Elliot et al. (1979) argue that improper socialisation (e.g. starting at home or school) would be the predominant factor leading to criminal behaviour. They mention two archetypical paths to delinquency: 1) weak integration and commitment to the social order and involvement in delinquent peer groups; or 2) initially strong bonds to the social order followed by attenuation and commitment to delinquent peer groups. Improper socialization may frame engagement with groups that engage in criminal acts, but also temperament. Instead of relying on a macro-social perspective, several sociologists have argued that the rise in criminal behaviour may primarily come from family disruption and not social disorganisation (e.g. Messner and Sampson, 1991; Sampson, 1987). The discussion on the social roots of criminality is highly political since the role of individual free will in criminal acts depends on the weight given to the social context in framing antisocial behaviour. The tenants of a rational approach to criminality are the ones that may give more weight to individual responsibility. Authors such as Cornish and Clarke (1986) assert that most aspects of criminal behaviour can be understood through the lens of bounded rational choice theory (following the concepts exposed in Simon, 1978). Cornish and Clarke (1986) first recognise that some crimes look at first sight like random acts of violence; often end up in non-utility-maximising failure or arrest; are rooting in deep-seated drives (e.g. sexual abuses); are pursued for existential reasons such as thrill seeking; or involve biological stages such as rage or arousal. Yet, most criminal outcomes, including often those described before, may be produced in a setup of bounded rationality according to these authors. For example, criminals may only take up into account only a few risks and benefits; only take limited time and effort before taking a decision, often under the influence of drugs and alcohol; may focus on the reward and not the possible punishment; and instantly react to a challenge or an insult. Cornish and Clarke (1986) pledge for applying the perspective of bounded rationality to specific types of crimes. They also consider that sociologists have far too often considered crime as a homogeneous category or looked at categories that are too broad. For example, car theft for juvenile joyriding is different from the theft of cars for exports. Within a given crime category, the motives of crime and their logics could appear clearer to the analyst.

¹² 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

Whether criminal acts embed some sort of rationality or not, temperatures are most likely to trigger criminal offenses within the subgroup of the population that is mentally ready to engage in criminal offenses. Temperatures should mostly trigger the expression of latent criminal behaviour among those subjects who have already displayed criminal attitudes or personality traits such as lack of self-control.¹³ Thinking of criminal behaviour as a structural component in the identity of a minority of (more or less rational) subjects has strong impacts on the mechanisms through which criminality operates and can be prevented. If criminality is a context-dependent behaviour of a minority group, it should be highly dependent on the interactions that criminals have with their own environment. For the object of this study, temperature may modify the way criminals interact with their (mostly urban) environment. This could explain rises in criminality.

Cohen and Felson (1979) 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.¹⁴ 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 impact criminality. Using U.K. data, Field (1992) is supportive of this view. 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 psychological effect. He concludes that criminality increases during hot days in the U.K. plausibly because households spend more time outdoors. Changes in time allocation would increase opportunities for criminals to act. In particular, more violent crimes should be recorded because these crimes tend to occur when people are far away from their homes.

and sexual offenders constitute a very heterogeneous category of offenders who are unlikely to suffer from the same cognitive distortions.

¹³ Another explanation for crime is culture-based. There might be cultures of violence among subgroups of a population. In the United States, scholars in the 70s have argued that there could be something such as a Southern culture of violence developed before the Civil War and explaining criminality levels in the 20th century (e.g. Gastil, 1971). Improper socialisation in the South would explain criminality in a way that is consistent with the above-mentioned sociological theories. In practice, the idea of a Southern culture of violence would suggest that temperatures would strongly correlate with criminality while having little to do with it. In practice, our view is that culture-driven theories give far too little space to personal choice. They can also be misused to back up unacceptably racist interpretations of criminality. In the US example, amalgamating criminal behaviour with Southern States could be an insidious way to associate violence with skin colour.

¹⁴ 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.

Instead of talking about routine activities, Hindelang, Gottfredson and Garofalo (1978) prefers the term of lifestyle to describe the fact that people's day-to-day activities could explain differences in victimization risk. The two terms are largely interchangeable since both identify changes in everyday activities to be a central factor of victimization risk. Yet, the term of lifestyle reflects that changes in lifestyle, more than activities, could produce violence and aggression. These “lifestyles” could be more frequent with a hot climate.

We can be quite concrete about the types of “lifestyles” that could emerge during hot days. Anderson and Bushman (1997) identify provocation and retaliations as the major reason behind most aggressions (physical or verbal), in support of a theory in which temperatures could alter perceptions about mild provocations and contribute to an escalation of violence. However, they also mention three other factors influencing aggressive behaviour in the short run: anonymity, alcohol and media violence. Out of these three factors, the interaction between anonymity and temperature and the interaction between alcohol and temperature could back up a lifestyle-based interpretation of the temperature-criminality relationship. 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. It is not the activities performed, but the group constitution that creates space for criminality. Likewise, temperatures may be associated with drugs or alcohol consumption, and indirectly lead to more crimes.

Relying on environmental psychology, Jeffery (1977) suggested modifying the built environment as an effective way to reduce criminality, with the view that the learning disabilities and behavioural problems that often lead individuals to criminal activity should be treated as any other psychological illness. Measures of crime prevention through environmental design are numerous. For example, some focus on making easier informal on site surveillance by neighbours or reducing access to privately owned areas (see Cozens, Saville and Hillier, 2005, for a review).

2.5. Summary of possible explanations

Table 1 summarizes the list of explanations found in the above-mentioned literature for the correlation between criminality and temperature. In the remaining of this paper, we consider that the psychological channel is only one possible explanation for heat-related criminality. We aim to evaluate the fitness of alternative economic, rational or behavioural explanations to the

evidence that we gather. We also analyse short-run dynamics and consider both permanent and transitional increases in criminality.

Table 1: Reasons for the association between temperature and crime

Channel	Effect	Impact on crime	Timing	Additionality
Taste for violence	High temperatures create discomfort and increase aggressiveness.	Increases in violent crimes.	Concomitant to high temperatures.	Crimes are not premeditated and are additional.
Taste for violence	Cognitive faculties are impaired by high temperatures.	Increases in opportunistic crimes since consequences are not properly evaluated.	Concomitant to high temperatures.	Crimes are not premeditated and are additional.
Higher marginal utility	Temperatures impact income.	Increases in economically motivated crimes (both violent and non-violent).	Days or weeks after a climatic event.	Crimes are additional and should be premeditated.
Higher marginal utility	Previous crimes during hot days reduce the benefit of committing subsequent crimes.	Reductions in criminality following peaks in criminality.	Days after high temperatures.	No additionality.
Lower dissuasion	Changes in temperatures make deterrence less effective.	Increases in either violent or non-violent crimes.	Concomitant to the change in temperature.	May or may not be additional since it could only accelerate decisions to commit crimes. Crimes should be premeditated.
Changes in social interactions	Criminals and victims adapt their schedules to temperatures.	Mostly increases in violent crimes if victims venture further away from their neighbourhoods.	Concomitant to the change in temperature.	Not all crimes may be additional since activities that would have been performed anyways may be delayed or advanced.
Changes in social interactions	More alcohol or drugs are being consumed during hot days.	Increases in violent crimes.	Concomitant to the change in temperature.	No premeditation but additionality, and higher possibility of accidents (involuntary offenses).

3. Data and summary statistics

For our analysis, we have gathered daily data on criminal activity, temperature, rainfall and humidity at municipality level in Mexico from 1997-2012.

3.1. 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

and prosecutions. Prosecutions include information on presumed criminals that have gone through a trial. 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 will be sentenced. In this paper, we concentrate on the accusations because we are primarily interested in the occurrence of crimes. We however use the data on 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.

The original dataset contains a wide range of over 400 detailed crimes types which we have aggregated into broader crime categories. Table 2 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 2 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.¹⁵ 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.

¹⁵ Please note that these terms 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).

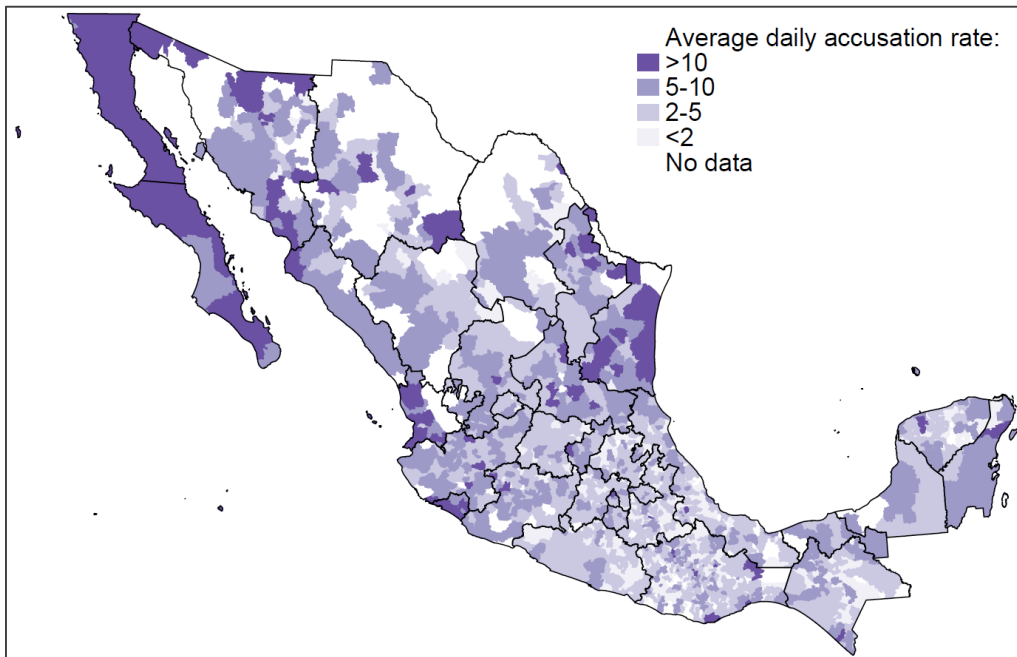
**Table 2: Average daily accusation and prosecution rates by type of crime and circumstance
(in accusations per million inhabitants, 1997-2012)**

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.

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



3.2. Weather and climate data

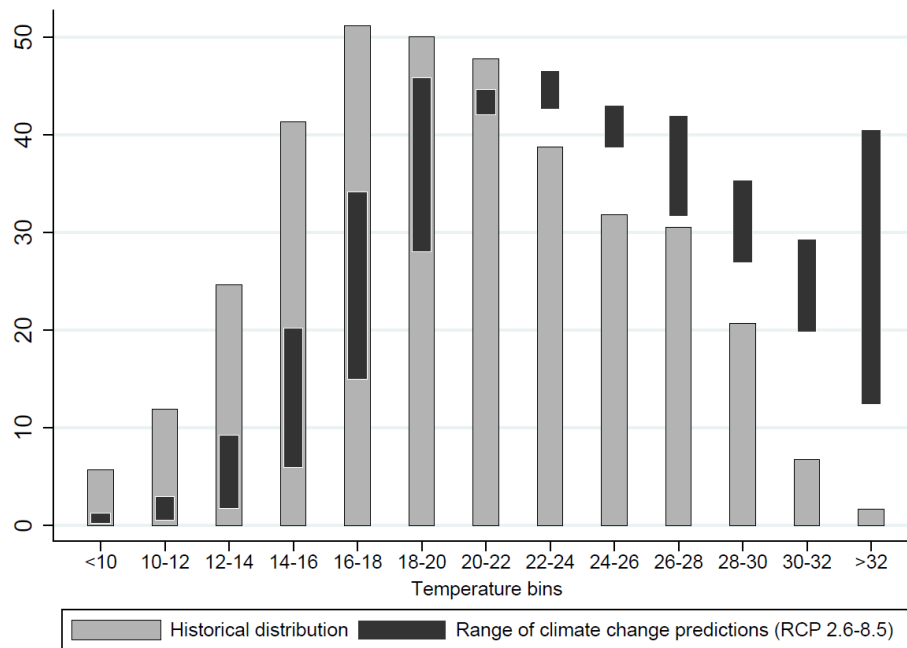
We have gathered daily temperature and precipitation data from the National Climatological Database of Mexico. Records correspond to the data from around 5,500 operating and formerly operating land-based stations in Mexico. However, the data has been aggregated at municipality level to match the criminality data.¹⁶

Figure 2 below presents the historical distribution of daily average temperatures in Mexico from 1997 to 2012.¹⁷ The data presented below is used in the econometric models later on. We have constructed 13 temperature bins: the “less than 10°C” bin is the lowest, the “more than 32°C” bin the highest, and there are eleven 2°C bins between them.

¹⁶ 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 considered to be relevant to a given municipality.

¹⁷ 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).

Figure 2: Distribution of hot and cold days in Mexico across 13 temperature bins (in °C) for historical data (1997-2012) and 2 climate change scenarios based on GFDL CM3 model output (2075-2099)



Notes: The Figure shows the distribution of daily average temperatures in Mexico across 13 temperature-day bins. Each light grey bar represents the average number of days in each temperature bin over 1997-2012. The climate change results depend on the scenario chosen (from RCP2.6 to RCP8.5). The dark grey bar represents the range that can be obtained with a low emissions scenario (RCP2.6) or a high emissions scenario (RCP8.5). The largest deviations from historical temperatures (upwards for high temperatures and downwards for low temperatures) are caused by the high emissions scenario.

The climate in Mexico is hotter than in most countries. 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.¹⁸ Furthermore, Mexico is expected to be heavily impacted by climate change, and therefore to remain one of the hottest spots in the world. Figure 1 provides information about the distribution of cold and hot days under climate change, based on the output of the Coupled Physical Model of the Geophysical Fluid Dynamics Laboratory (GFDL CM3) of the National Oceanic and Atmospheric Administration (NOAA). Our estimates are derived from the monthly average temperature predictions for 2075-2099 and three IPCC emissions scenarios (RCP2.6, RCP4.5 and RCP8.5). For each month of the year, we have computed the difference between the monthly predictions and the historical averages,

¹⁸ We may compare this climate with the US climate, for example. 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).

and then added this difference to all the observed temperature levels in our dataset to make a forecast of the distribution of days that will fall within each temperature bin. We make the simplifying assumption that climate change does not alter the variance of the distribution of hot and cold days, but just the average.¹⁹

4. The impact of daily ambient temperatures

4.1. Empirical strategy

In this paper, we correlate daily accusation records (also prosecutions and convictions) with daily temperatures while controlling for most municipality-level changes in average accusation rates. 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 municipality-by-month-by-year fixed effects. These fixed effects control for all unobservable characteristics of 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:

$$Y_{i,d,m,t} = \theta \cdot T_{i,d,m,t} + \mu_{i,m,t} + \varepsilon_{i,d,m,t}$$

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 in a given month in a given year.²⁰

The regression coefficients need to be weighted by the population or by the square root of the population in each municipality²¹ because without any weights, the coefficients would be representative of municipalities and not the population. Furthermore, $Y_{i,d,m,t}$ is noisily estimated

¹⁹ We obtain the model output from the *Atlas Climático Digital de México*. This Atlas provides climate model output for Mexico online and is monitored by *Centro de Ciencias de la Atmósfera* of the *Universidad Nacional Autónoma de México* (UNAM).

²⁰ In an alternative specification, we have also used State-level clusters to relax the hypothesis of zero correlation between municipalities, and zero correlation between observations of a same municipality but pertaining to a different month or year. Standard errors slightly increase and the statistical significance of the effects remains.

²¹ Deschenes and Moretti (2009) use total population as a weight. We are using the square root. Using total population instead of the square root has no significant impact on the results.

in small municipalities and the effect of such noise on the estimation is mitigated with the use of population-based weights.

The vector $T_{i,d,m,t}$ includes our climatic variables of interest. Since the accusation-temperature relationship might be non-linear, the most conservative approach consists in using temperature bins to specify the relationship between temperature and accusation, as it has been done in other applications, e.g. mortality or 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 $T_{i,d,m,t}$. The lowest bin covers days with temperature below 10 Celsius degrees, and the highest bin covers days with temperature above 32 Celsius degrees.

The aforementioned model does not take into account that criminal's response to high or low temperatures may be delayed. For example, criminals may wait for good climatic conditions before acting. Therefore, good or bad weather could delay or accelerate criminal acts without having any additional effect on the total amount of criminal activities. In fact, some criminal activities are unlikely to occur twice over a short time period (e.g. murders). However, criminal acts could be followed by retaliations: if high or low temperatures trigger murders or thefts among cartels, cold or hot days could be followed by days with higher accusation levels.

When daily data is available, Deschenes and Greenstone (2011) suggest using a distributed lag model to account for dynamic effects. Our main model considers 12 temperature bins and include 20 lags for each bin:

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

We chose the number of lags to include the past 3 weeks to be able to observe short-term displacement effects and possible effects of immediate retaliation or imitation. In Appendix A, we have allowed 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. On the other side, 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.

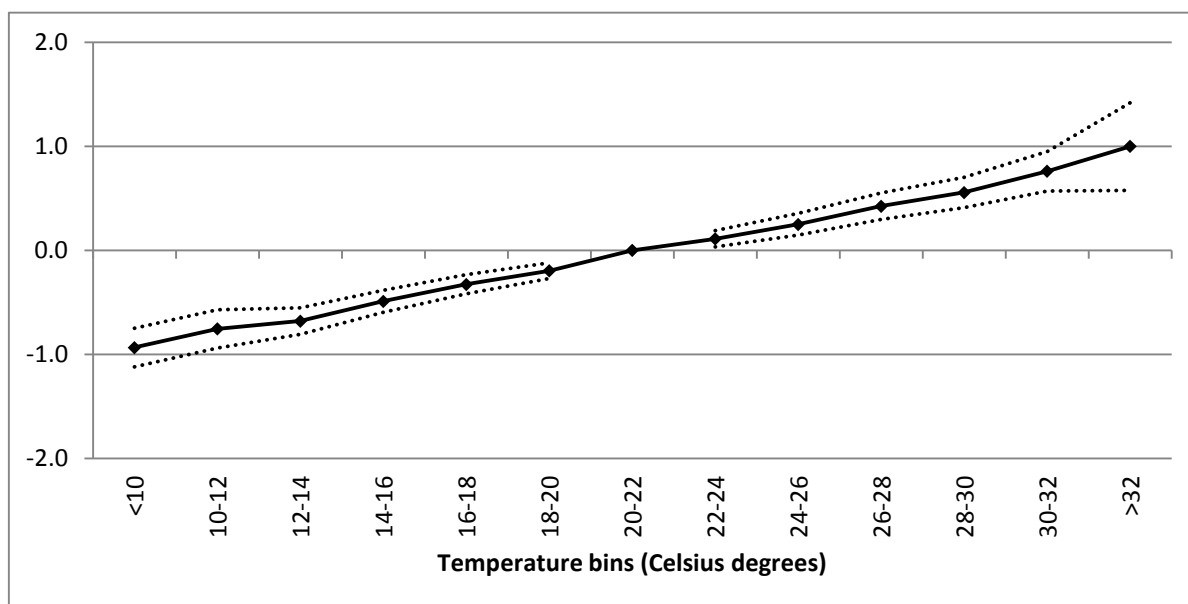
Above, the subscript s stands for the various temperature bins, and $B_{s,d-k,i}$ is a dummy variable equal to one if the temperature in day $(d-k)$ of district i falls within bin s . Furthermore, we use on-the-day average precipitation ($P_{i,d,m,t}$) to control for the confounding effect of precipitations 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. 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.

In what follows, we first present the results for the contemporaneous correlation between temperature and accusations to analyse the temperature–accusation relationship. We use data on accusations, and not prosecutions, since we think that it is a better reflection of the quantity of crimes being committed in Mexico. Second, we use a distributed lag model to analyse if criminals delay or accelerate their activities. Then, we reproduce the analysis by breaking down accusations into ten different types of criminal activities.

4.2. General results

The contemporaneous correlation between temperature and criminal activities is reported in Figure 3. We find a quasi-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 ($<10^{\circ}\text{C}$) and a hot day ($>32^{\circ}\text{C}$) is sizeable: it corresponds to an increase by 1.9 daily accusations per million inhabitants, roughly equal to a third of the average daily accusation rate. Therefore, the weather appears to be a very good predictor of the frequency of criminal activities.

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

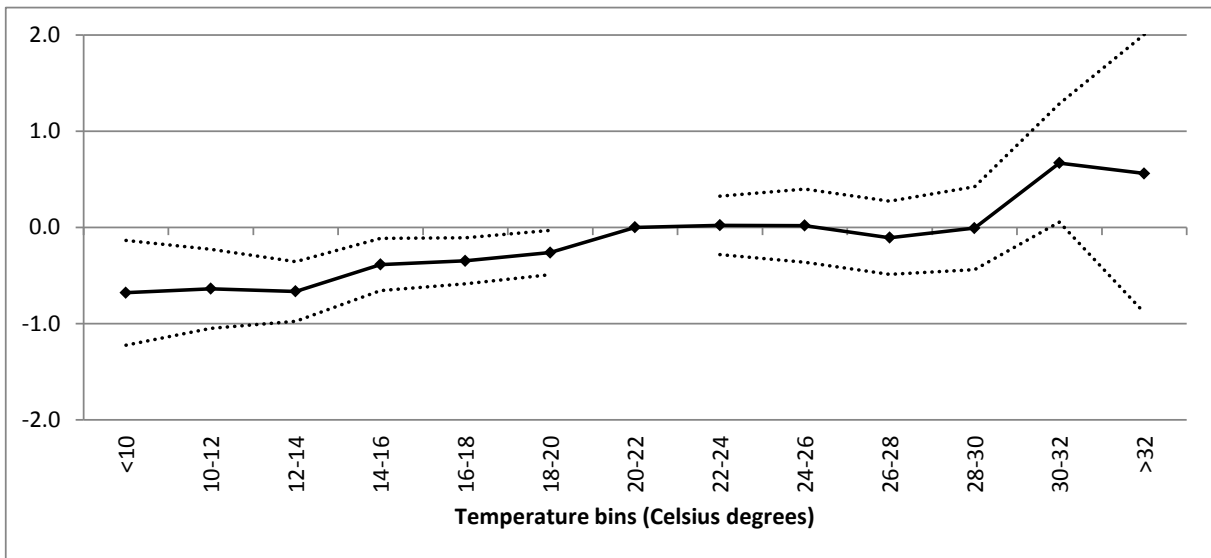


Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The regression also includes municipality by-month by-year fixed effects and is weighted by the square root of the population in each municipality. 95% confidence intervals are 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 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. 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 distributed lag model, against 1.9 crimes per million inhabitants with a simple correlation with contemporaneous temperatures (the effect is 35% lower). In the middle of the distribution of temperatures, we observe attenuated effects with a distributed lag model for days between 10°C and 18°C, and no additional effect for days between 22°C and 30°C as compared to days with a temperature of 20-22°C.

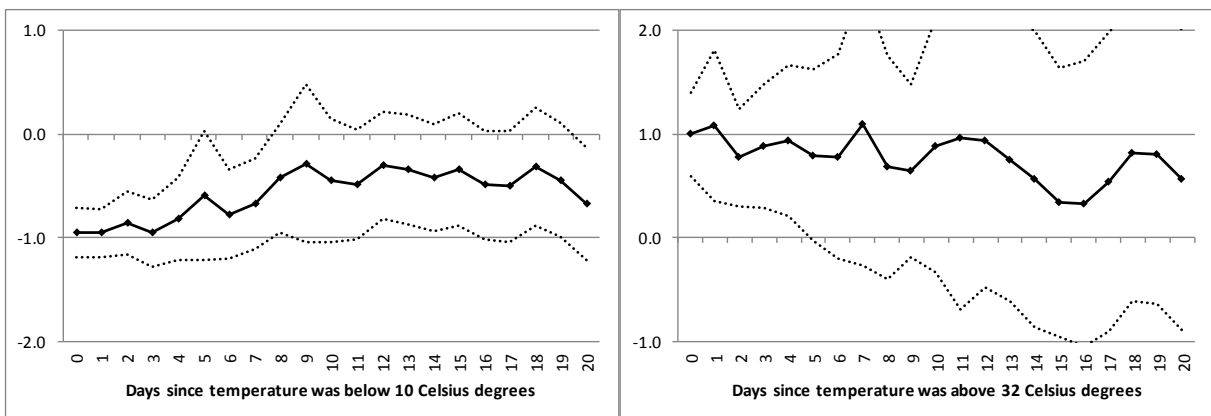
Figure 5 looks at how the effect of days below 10°C (left panel) and above 32°C (right panel) on accusation accumulates over 21 days. It shows that, whereas there is a high correlation between on-the-day temperature and accusation, higher accusation rates are observed on the days following a very cold day (left panel), and lower accusation rates are observed on the days following a very hot day (right panel). It follows that only one part of the crimes committed during hot days are additional crimes, whereas the others would have been committed anyways in the following days.

Figure 4: 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 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 5: Roll-out 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 4. 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 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.

One reason for this effect is that some criminals may wait for climatic conditions to be as good as they can be before acting. Another reason, mentioned by Jacob, Lefgren and Moretti (2007),

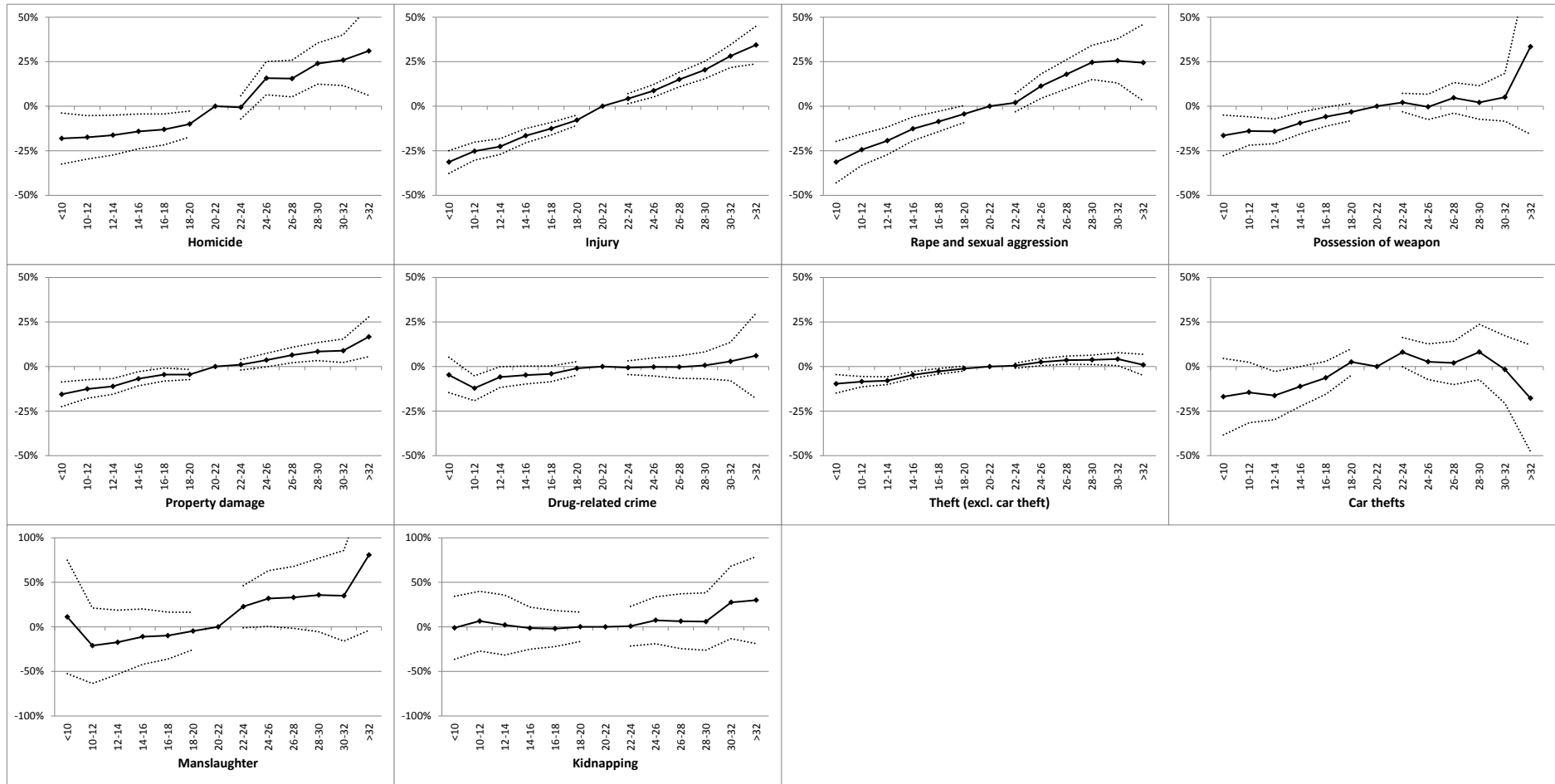
is that the marginal benefit of committing a crime might be a decreasing function of the number of crimes already committed by an individual. Once a crime of a certain type is committed, the offender may have lower incentives to commit a similar crime again, particularly in the short run.

4.3. Results by type of crime

By breaking down the accusation rate by type of crimes, it is possible to identify crimes that are most likely to occur during hot days. Figure 6 reproduces the regression that correlates on-the-day temperature with accusation rates for the ten types of crimes listed in Table 2 (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 and previously reported on Table 2. We find that accusations for violent crimes (homicide, injury, rape and sexual aggression and possession of weapon) are the most correlated with hot weather: there is an increase equivalent to 50% of the average accusation rate during unusually hot days ($>32^{\circ}\text{C}$) compared to unusually cold days ($<10^{\circ}\text{C}$). 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 though since these events are less frequent in our dataset.

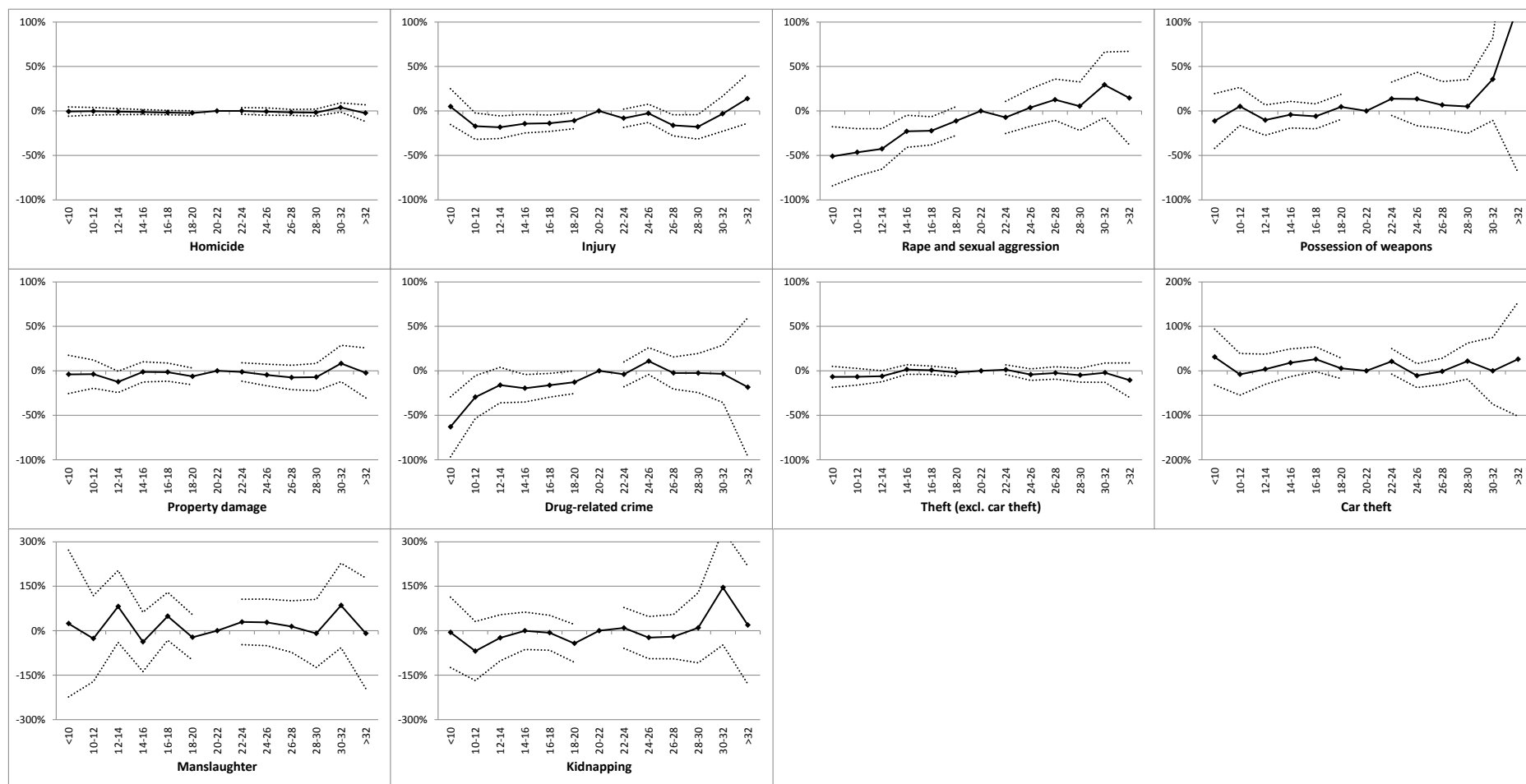
Figure 7 accounts for displacement effects using a distributed lag model of each type of crimes. After 21 days, we find no statistically significant impact of high temperature on most categories of crimes. The result is particularly sharp for homicides, property damage and thefts, but also holds for injuries and possession of weapons. This is consistent with the explanation given by Jacob, Lefgren and Moretti (2007) on the decreasing marginal benefit of committing a crime. 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. As for homicides, the same person cannot be killed twice: the value of killing again might very well become null, from the offender's perspective, once the first homicide has been successful. The result of a strong correlation between temperature and accusation rates remains for rapes and sexual aggressions and, to a lesser extent, for drug-related crimes: these two types appear to be less frequent when temperatures get below 20°C . We show later on that the effect on drug-related crimes could be due to a supply-side effect: crop yields for marijuana and opium may suffer from low temperatures. We further discuss the effect on rapes in section 5.

Figure 6: 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

Figure 7: 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

4.4. Robustness

We have run several robustness checks to ensure that our results do not depend on specification choices. We refer the reader to appendices B to F for more detail.

In Appendix B, we check if our results are partly imputable to precipitations. Since precipitations and temperatures are correlated, the effect of temperature on crime could be confounded by the impact on 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.

In Appendix C, 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.²² In a similar fashion, we assessed if the temperature-criminality relationship was different across four climate regions in Appendix D: very warm and warm regions (covering very dry, dry, semi-dry, humid and semi-humid regions that are also very warm and warm); semi-warm; temperate; and semi-cold or cold regions (covering respectively all semi-warm, temperate, semi-cold or cold regions independently of humidity). In all regions, we find that an increase in temperature correlates with an increase in criminality, even though results lose precision at the extremes, when observations become very scarce for one climate (e.g. cold days in hot areas). However,

²² Since they provide not additional insight and for the sake of concision, results with consecutively hot and cold days are not reported.

results are not conclusive for cold areas. This is not surprising because very few mountainous areas would classify as cold.

In Appendix E, we divided our sample in two periods: 1997-2004 and 2005-2012. Results for 1997-2004 are inefficient and only weakly capture the correlation between temperature and crime. Results for 2005-2012 are much clearer. The difference in the efficiency of the results obtained is likely to stem from an increase in data quality over time.

In Appendix F, we have run the distributed lag model separately for municipalities with less and with more than 10,000 inhabitants. We find that a relationship only for municipalities with more than 10,000 inhabitants. In fact, criminality is mostly an urban problem and we may lack efficiency to capture effects in smaller areas.

Finally, we checked if our results were robust to changes in the structure imposed on the fixed effects. Details are in Appendix G. 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 very similar. As in our main distributed lag model, we find that the difference between a cold and a hot day is around 0.1 offenses per million inhabitants.

4.5. Climate change impacts

The distribution of temperatures under climate change (see Figure 2) can be used to compute the number of crimes triggered by high temperatures that might occur under climate change in Mexico. While this exercise provides information about the magnitude of the impacts that we have uncovered, there are a few limitations. First, we can only account for modifications in the short term effects of temperature on criminality. Longer term impacts through changes in agricultural yields, induced migration, among others are not captured. Moreover, we assume similar demographics and technologies to prevent crime.

We produce a climate change forecast by multiplying the estimated coefficients of Figure 3 and Figure 4 by the average number of days falling in each temperature bin. We take care of weighting this average number of days by the population in each municipality, and assume a constant population of 120 million inhabitants. For concision, we only report the main results

for the intermediate, RCP4.5 scenario, in Table 3.²³ We find that predictions are sensibly different if displacement effects are considered. In general, we find that climate change will lead to 10,773 more accusations annually in the contemporaneous model. With an average amount of accusations of around 250,000 crimes per year for 120 million inhabitants, climate change would increase the accusation rate by 4.3%. This figure is 22% lower when we account for dynamic effects in the distributed lag model, falling down to a 3.3% increase in the accusation rate. Yet, we cannot exclude the possibility that both figures are equivalent at standard confidence levels.

Table 3: Impact of climate change on annual accusations in the RCP4.5 climate scenario

Type of crime	Estimates with on-the-day correlation	Estimates with distributed lag model
All crimes	10,773* (8,877–12,670)	8,416* (3,621–13,211)
Homicide	654* (343–966)	202 (-384–788)
Injury	3,053* (2,499–3,607)	1,451* (304–2,597)
Rape and sexual aggression	440* (247–633)	727* (346–1109)
Possession of weapons	814* (242–1,386)	1927 (-169–4023)
Property damage	904* (581–1,227)	243 (-424–911)
Drug-related crime	245 (-128–619)	776 (-244–1797)
Theft (excl. car theft)	1,458* (896–2,019)	-213 (-1481–1055)
Car theft	11 (-45–67)	-23 (-135–89)
Manslaughter	35 (-2–73)	-1 (-81–79)
Kidnapping	32 (-78–142)	146 (-125–417)

Notes: the 95% confidence interval in brackets only take into account the uncertainty of the impact of temperature bins on accusation. Statistically significant results at 5% are marked with a (*). It does not take into account the uncertainty of climate models in the magnitude of daily temperatures. Estimates are obtained while assuming a Mexican population equal to 120 million inhabitants.

Whereas we find statistically significant impacts for most crime categories in the contemporaneous model, only rape and sexual aggression, and injuries remain statistically significant in the distributed lag model. The absolute figures correspond to a relative increase

²³ The results for the RCP2.6 scenarios are in the same lines, but attenuated, with a total number of additional crimes equal to 6,205 (3,037–9,373) when using the coefficients from the distributed lag model. With the RCP8.5 scenario, this figure reaches 11,993 (3,400–20,587).

in crime rates by 10.6% for rapes and sexual aggressions, and 3.9% for injuries. The result for injuries should be interpreted with caution since the 21-day relationship between temperature and injuries is unclear, as per Figure 7.

4.6. Comparison with other studies

It is interesting to compare our results with at least four studies. Ranson (2014) performs a similar analysis of the impact of temperatures on criminality in the U.S. Our general estimate lies in the same order of magnitude as Ranson (2014). 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 US are not exposed to the same temperature range. The impact of temperatures on a few crime categories appears to be non-linear, both in Ranson (1994) and in our study, suggesting that a 1°C temperature increase could produce radically different effects in the U.S. and Mexico.

In this respect, the study by Baysan *et al.* (2015) is more closely related to ours since it also relies on Mexican data. Baysan *et al.* (2015) find 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, possibly the effect of heat on human psychology. 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 psychological 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 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. We dig into this aspect in section 5 and 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 also interesting to compare our results with those in Fields (1992) for the UK. 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) and concludes that this increase is caused by a change in activities of UK 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).²⁴ Therefore, the figures in the case of Mexico as higher but comparable to the UK evidence. This suggests that similar underlying factors could explain the temperature–criminality relationship. Yet, Mexico is very hot whereas U.K. temperatures are almost never above 25°C (even in the South).

Finally, we find strong displacement effects, as in Jacob, Lefgren and Moretti (2007) for the U.S. which suggests that similar mechanisms are at play in Mexico and in the U.S.

5. Understanding the channels

At this stage, we have gathered several pieces of evidence on the nature of the relationship between temperature and criminality. First, impacts are found to be linear in temperature, and

²⁴ 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).

only remain statistically significant after 20 days for bins below 20°C. Hence, excessive heat cannot be deemed the only explanatory factor for the correlation between temperature and crime. Likewise, a purely psychological or physiological route cannot explain the correlation between temperature and criminality on its own: it has to be supplemented with other explanations.

On the other side, sharp displacement effects are more aligned with rational or behavioural arguments than with psychological explanations. If offenders are mentally fragile enough to commit crimes because of heat, then we should expect that they act as recidivists, as soon as other stressors get activated (in the following days). Displacement effects suggest that crimes are committed for purposes more fundamental than heat. Plausible interpretations are that rational criminals could take advantage of hot weather to commit a crime that they wanted to perpetrate anyways. Also, there might be decreasing benefits in committing the same crime twice. Alternatively, hot days could increase social interactions and therefore concentrate all criminal-victim encounters at the same time. In the absence of a hot day, these encounters would have spread out over the course of one or two weeks.

Yet, we are sure of a time-persistent impact of temperatures on rapes and drug-related crimes. Hereafter, we find that temperature below 0°C explain the net decrease in drug-related crimes. This suggests that drug production might be affected by frost damage. On the other hand, rapes and sexual abuses have no financial implication. A totally different channel than the economic one should be at play to explain the persisting correlation between temperature and rapes.

In the remaining of the paper, we undertake five complementary analyses to identify if either a rational or a behavioural channel could serve as an alternative explanation to the correlation between crime and the weather. Future versions of this working paper will also test for the hypothesis of a higher taste for violence, looking at the outdoor exposure of criminals to warmer temperatures, and the mitigating effect of AC and heating. At present, we ask the following questions:

1. Were offenses intentional or unintentional?
2. Is the judicial system more or less effective to deal with crimes committed during hot days?
3. Are offenders using drugs or consuming alcohol?
4. Were offenses committed during the week or the weekend?
5. Were they committed during day-time or at night?

Table 4 summarises the hypotheses that we test thanks to these five questions: positive or negative answers to these questions shed light on the mechanisms at play. For example, lower dissuasion implies that impunity has to be higher during hot days. If this is not the case, then it would cast doubt on the idea that this channel is the main driver of the relationship between temperature shocks and criminal activities.

Table 4: Questions asked and their implications

Question	Channel being challenged	Explanation
Were offenses intentional or unintentional?	Lower dissuasion	Offenses have to be intentional for the rational channel to be at play.
Is the judicial system more or less effective to deal with crimes committed during hot days?	Lower dissuasion	Impunity should be higher if deterrence is impaired.
Are offenders using drugs or consuming alcohol?	Changes in social interactions	Changes in habits associated with higher criminality should occur if the behavioural channel is at play.
Were offenses committed during the week or the weekend?	Changes in social interactions	Adaptation to the weather has to be stronger during weekends since people are not constrained by work obligations.
Were they committed during day-time or at night?	Changes in social interactions	Night temperatures can be comfortable during hot days. The behavioural channel implies that potential victims should also go out more at night.

5.1. Intentions

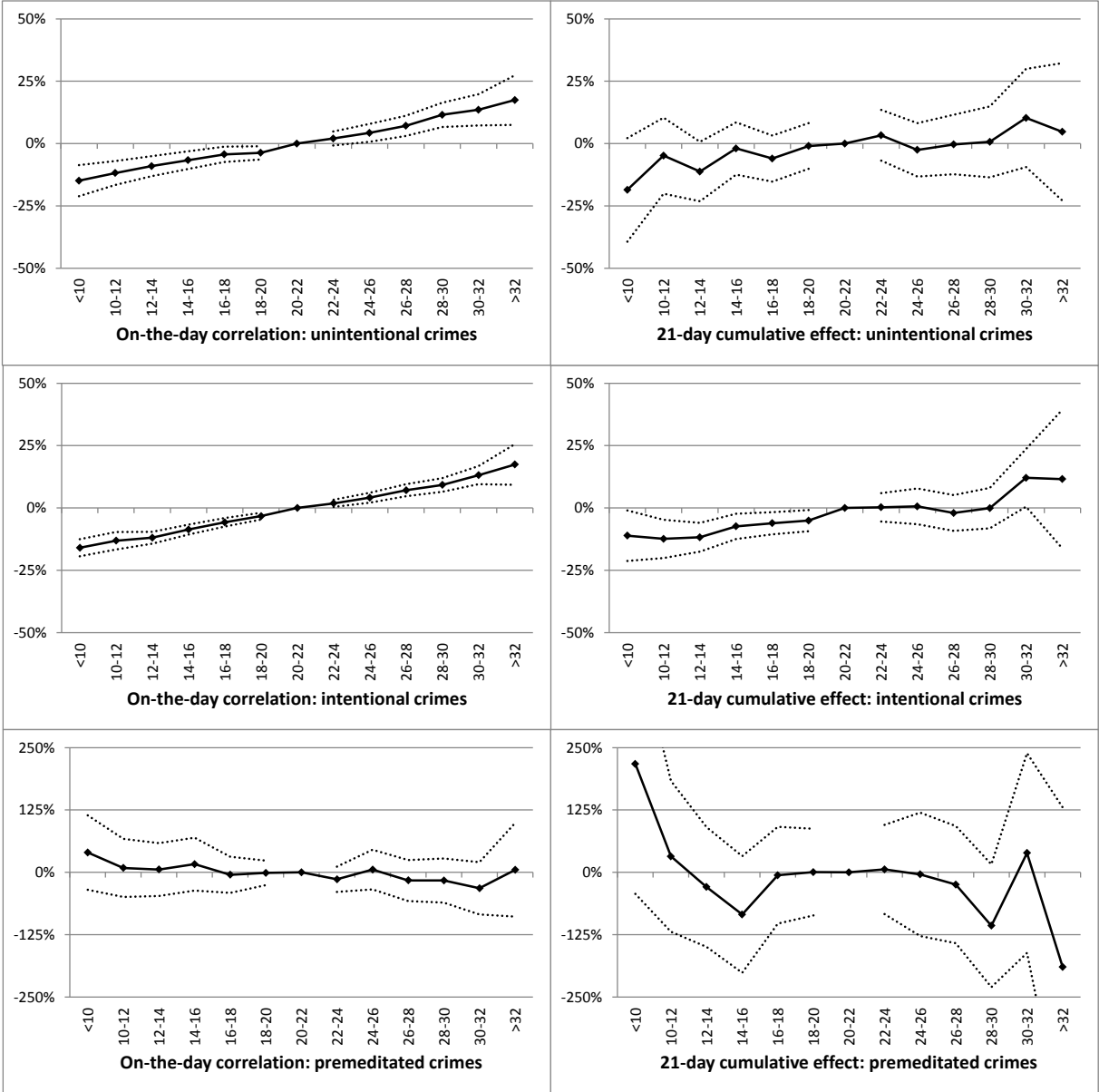
The intentionality of the crimes provides valuable information because if offenses were committed “by mistake”, e.g. road accidents, then we would be discarding the idea that criminals were opportunistic.

Intentionality is one of the variables recorded in the data on accusations. More precisely, the data makes the distinction between unintentional, intentional and premeditated crimes. Intentional crimes are the ones committed voluntarily but with no planning, whereas the premeditated crimes are carefully planned.

Figure 8 separates the effect of temperature on accusations according to intentionality. Unintentional crimes are on the upper panels, intentional crimes in the middle, and premeditated crimes on the lower panels. Results for the contemporaneous model are on the left, and the right panels display the outcome of distributed lag models (the long-run multiplier of each temperature bin after 21 days). Results for unintentional and intentional crimes look very similar: there seems to be an effect of hot temperatures on increasing the number of crimes in the short run, and eventually after 21 days (although this is imprecisely estimated). The orders of magnitude for these two types of crimes seem similar. Alternatively, results for premeditated

crimes seem to indicate that there is no effect of temperatures on premeditated crimes, but this is imprecisely estimated, plausibly because we lack of statistical power since this category is rather infrequent.

Figure 8: on-the-day and 21-day cumulative effect of temperatures on the daily accusation rate for unintentional, intentional and premeditated crimes



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. On the left panels, the y-axis reports the contemporaneous effect of temperatures on accusation rates for unintentional crimes (upper left panel), intentional crimes (middle left panel) and premeditated crimes (lower left panel). On the right panels, the y-axis reports the long-run multiplier of each temperature bin on the accusation rates for unintentional crimes (upper right panel), intentional crimes (middle right panel) and premeditated crimes (lower right panel). 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

These results suggest that about 9.4% of weather-related crimes are unintentional. Hence, most weather-related crimes are intentional. Yet, they do not seem to be premeditated, even though the absence of any effect for premeditated crimes could be caused by a lack of statistical power.

5.2. The judicial treatment of heat-related offenses

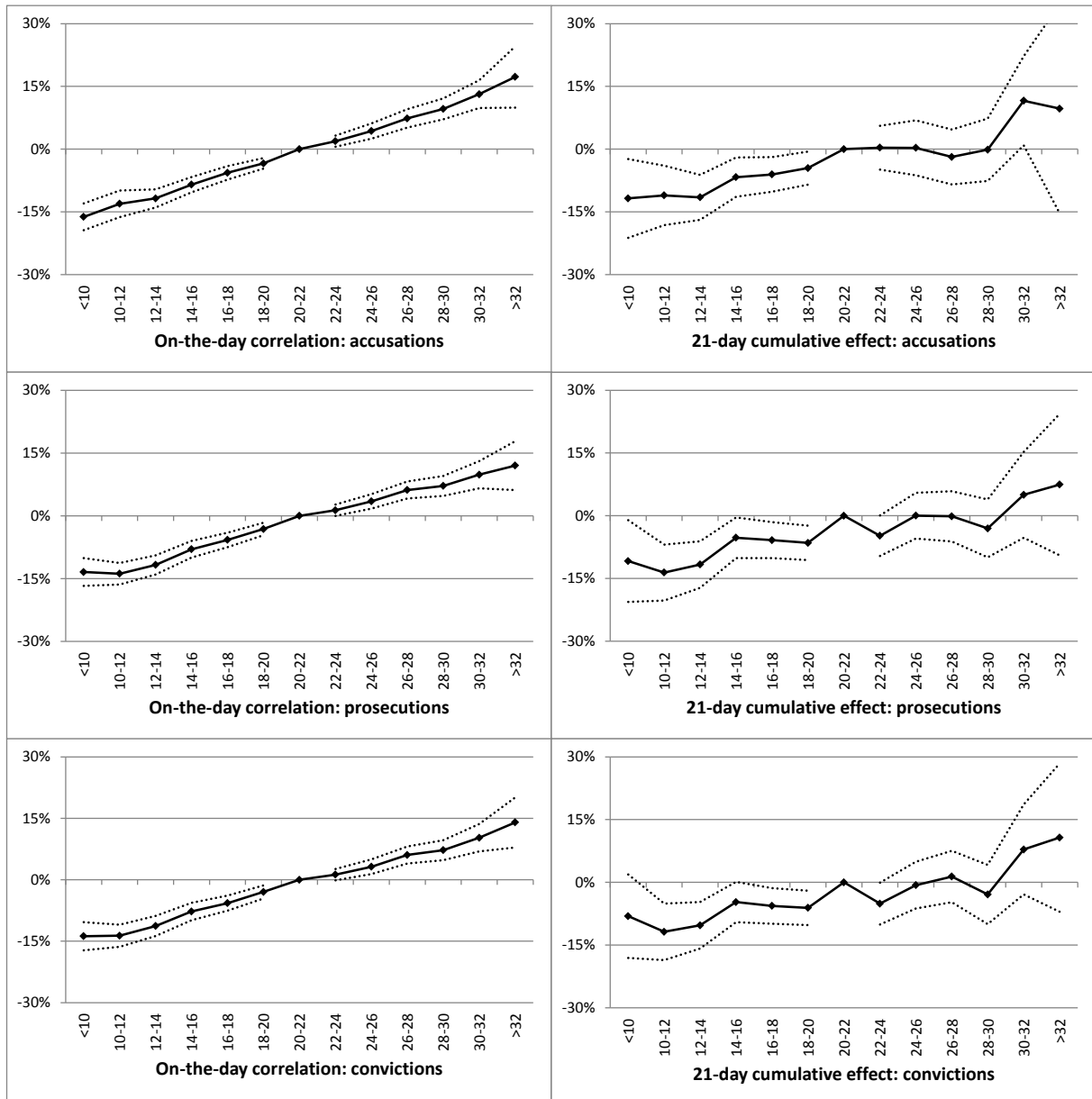
So far, we have used the data on accusations and not on prosecutions or convictions since we wanted information on the frequency of crimes and not their resolution by the judicial system. Yet, the same econometric exercises can be conducted with the data on prosecutions in Mexico and compare the figures obtained with accusations. If criminals act during hot days because they have fewer risks to be caught, the correlation between hot days and prosecutions should be smaller than the relationship between hot days and accusations. Furthermore, we can assess whether prosecuted criminals were found guilty of the crime or not. We would expect that the link between temperature and accusations is steeper than the link between temperature and convicted criminals if they can get away more easily with crimes committed during hot days.

Results for all crimes are provided in Figure 9. The results with the accusation rates are redisplayed and rescaled (to ease comparison) on the upper panel, whereas the results for the prosecution and conviction rates are respectively on the middle and lower panels. Prosecuted offenders undergo a trial, and convicted offenders are found guilty of the charge (88% of cases). The left panels provide the output of the on-the-day correlations, while the right panels consist of the results of distributed lag models.

We find exactly the same results with accusations, prosecutions and convictions, implying that committing a crime during a hot day apparently does not provide better chances of getting away with it. For concision, we are not reporting the results by types of crimes. Yet, we have performed the analysis and using prosecutions or convictions instead of accusations and the results by type of crime are very similar. For all the considered types of crime, committing a crime during a hot day apparently does not provide either better or worse chances of getting away with the crime. We consider that this result corroborates the idea that hot days do not provide better opportunities than normal days to commit most criminal offenses, even though most crimes during hot days prove to be intentional.

It follows that lower deterrence during hot days may not be the main contributing factor to explaining the correlation between temperatures and criminality. We now turn to analysing the contribution of the behavioural channel.

Figure 9: Comparison of results obtained with the accusation vs. the prosecution and conviction rates (all types of crimes)



Notes: each graph corresponds to a separate regression. The dependent variables are the daily accusation rate (upper panel), prosecution rate (middle panel) and conviction rates (lower panel) as a share of the average rate of each category. The independent variables are all the listed temperature bins and the amount of precipitation in the day. On the left panels, the y-axis reports the contemporaneous effect of temperatures on accusation rates. On the right panels, 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. The reference bin is 20-22 Celsius degrees.

5.3. Psychophysical status

Higher alcohol consumption or drug usage could partly explain crime rates during hot days. Our dataset reports if the offenders were in a normal state, or consumed drugs or alcohol. Figure 10 separately reports the results of our two econometric models for these three groups of

offenders. Offenders in a “normal state” are in the upper panels, drunk offenders in the middle, and drugged ones in the lower panels. Results for on-the-day correlations are on the left, and the right panels display the outcome of distributed lag models.

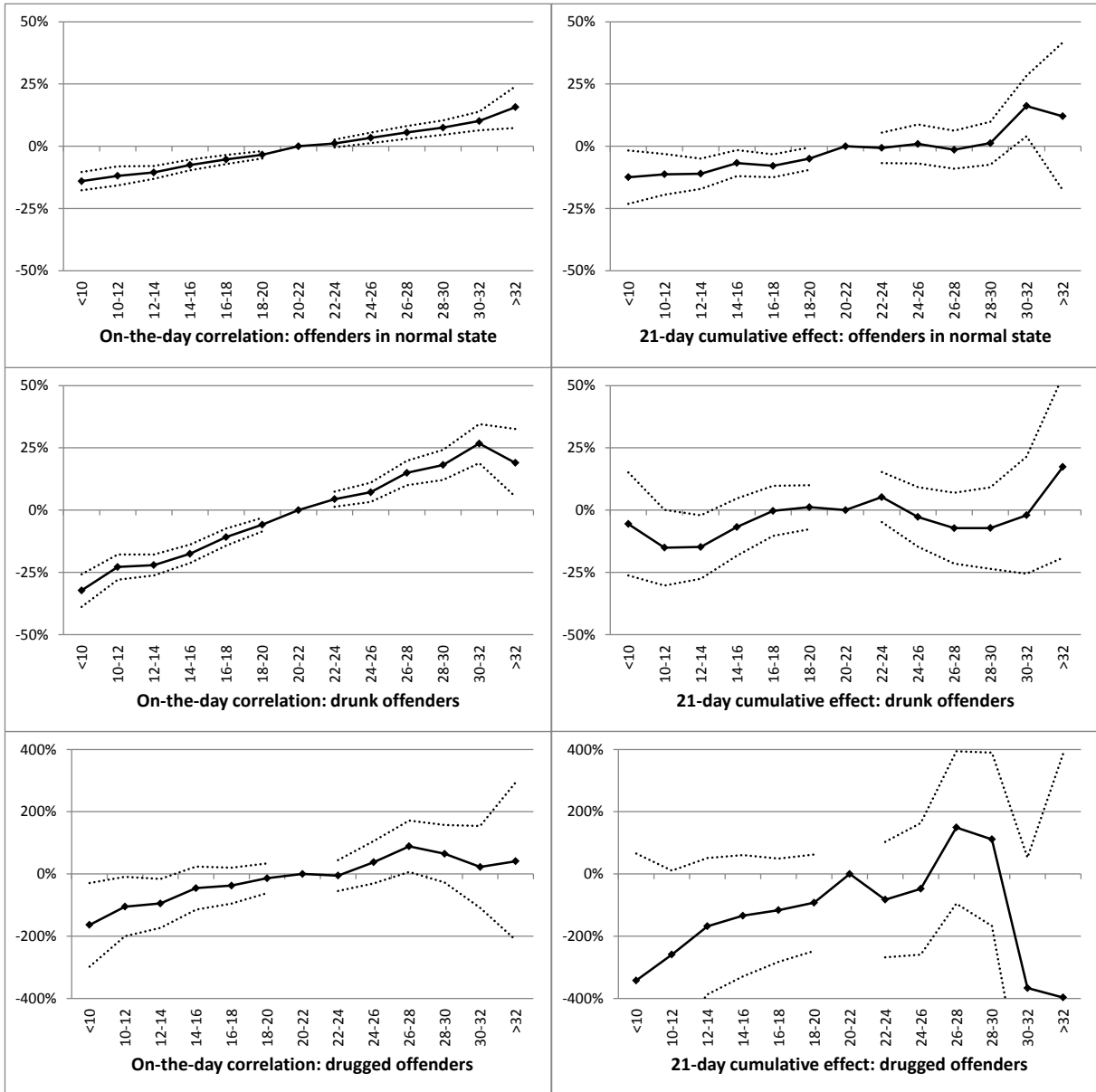
The on-the-day correlation between accusation rates and temperatures is steeper for drunk offenders as compared to the ones in a normal state, suggesting that a share of heat-related offenses is triggered by the consumption of alcohol. More precisely, the difference in the rates of accusation between an unusually cold ($<10^{\circ}\text{C}$) and an unusually hot day ($>32^{\circ}\text{C}$) represents around 30% of the average daily accusation rates for offenders in a normal state. This figure reaches 50% for drunk offenders. In our dataset, there are about 0.82 accusations per day and per million inhabitants that are committed in Mexico under the influence of alcohol. This implies that, as compared to an unusually cold day ($<10^{\circ}\text{C}$), the accusation rate may be higher during an unusually hot day ($>32^{\circ}\text{C}$) by about 0.17 points because more alcohol is being consumed.²⁵ Since the difference between a cold day ($<10^{\circ}\text{C}$) and a hot day ($>32^{\circ}\text{C}$) corresponds to an increase of 1.9 daily accusations per million inhabitants, higher alcohol consumption during hot days may therefore explain around 9% of the increase in the accusation rates found during hot days ($>32^{\circ}\text{C}$) as compared to cold days ($<10^{\circ}\text{C}$).²⁶ While this figure is rather small, it still implies that changes in behaviour (through higher alcohol consumption) explain at least 9% of weather-related crimes.

There are too few offenses committed under the influence of drugs to find statistically robust evidence for this category. Likewise, the distributed lag models do not allow us to find statistical different results for these three groups.

²⁵ This is: $0.86 \times (50\% - 30\%)$

²⁶ $0.17 / 1.9 \approx 9.0\%$

Figure 10: On-the-day and 21-day cumulative effect of temperatures on the daily accusation rate for offenders in a normal state vs. drunk and drugged 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), drunk offenders (middle panels) and drugged offenders (lower panel) as a share of the average rate of each category. The independent variables are all the listed temperature bins and the amount of precipitation in the day. On the left panels, the y-axis reports the contemporaneous effect of temperatures on accusation rates. On the right panels, 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. The reference bin is 20-22 Celsius degrees.

5.4. Weekdays vs. weekends

Whether heat-related crimes were committed during weekdays or weekends also matters. 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 11 separately estimate the effects of on-the-day temperature (upper panels) and a 21-day cumulative effect (lower panels) for weekdays (left panels) and weekends (right panels). We find that both 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.^{27, 28} Therefore, stronger changes in activities during weekends seem to partially explain changes in accusation levels. In general, around 40% of heat-related offenses occur during weekends.²⁹ We also calculate the proportion of heat-related crimes that occurred in weekends and would not have occurred if all days were weekdays. This roughly represents 17% of all heat-related crimes.³⁰ This unambiguously suggests that changes in time allocation associated with weekends are a contributing factor to heat-related accusations.

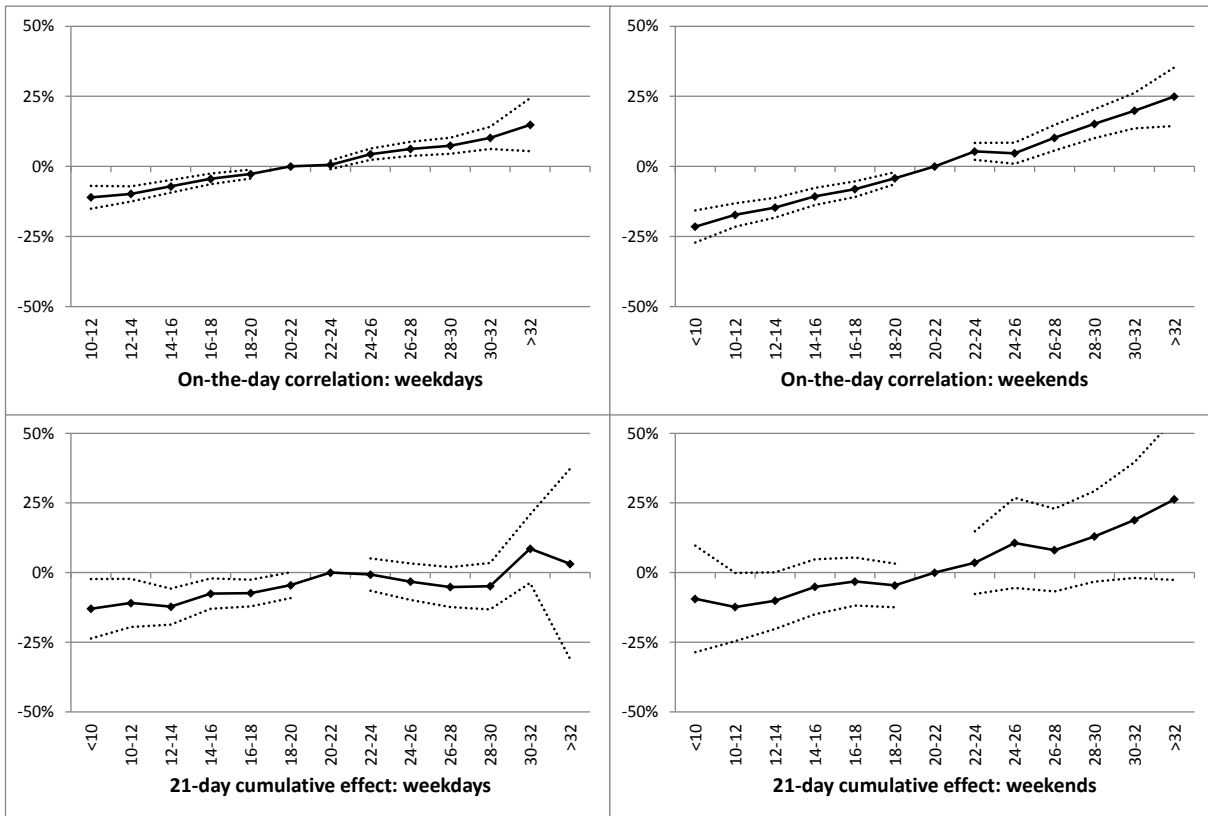
²⁷ Most of the coefficients of the two curves displayed on the upper panels of Figure 11 are statistically different from one another.

²⁸ 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 types of crimes. We have observed no strong differences in this pattern for different types of crimes, and decided not to report these results for the sake of concision.

²⁹ The accusation rate is respectively 5.6 and 6.1 accusations per million inhabitants during weekdays and weekends. A day above 32°C increases this rate by about 15% in weekdays and 25% in weekends. Therefore, in a week at 32°C, there would have respectively 4.1 and 3.0 accusations per million inhabitants made for events related to heat and occurring during weekdays vs. the weekend (5.6 x 15% x 5 and 6.1 x 25% x 2).

³⁰ The accusation rate increases by 25% during a hot day that occurs in the weekend, vs. by 15% for a hot day occurring during a weekday. The additional effect of weekends on the accusation levels recorded on hot days is 10% of the accusation rate of weekends (at 6.1 accusations per day and per million inhabitants). This is a total of 1.2 accusations during a week with all days above 32°C, or about 17% of all accusations caused by all hot days above 32°C during a week.

Figure 11: On-the-day and 21-day cumulative effect of temperatures on the daily accusation rate during weekdays and weekends



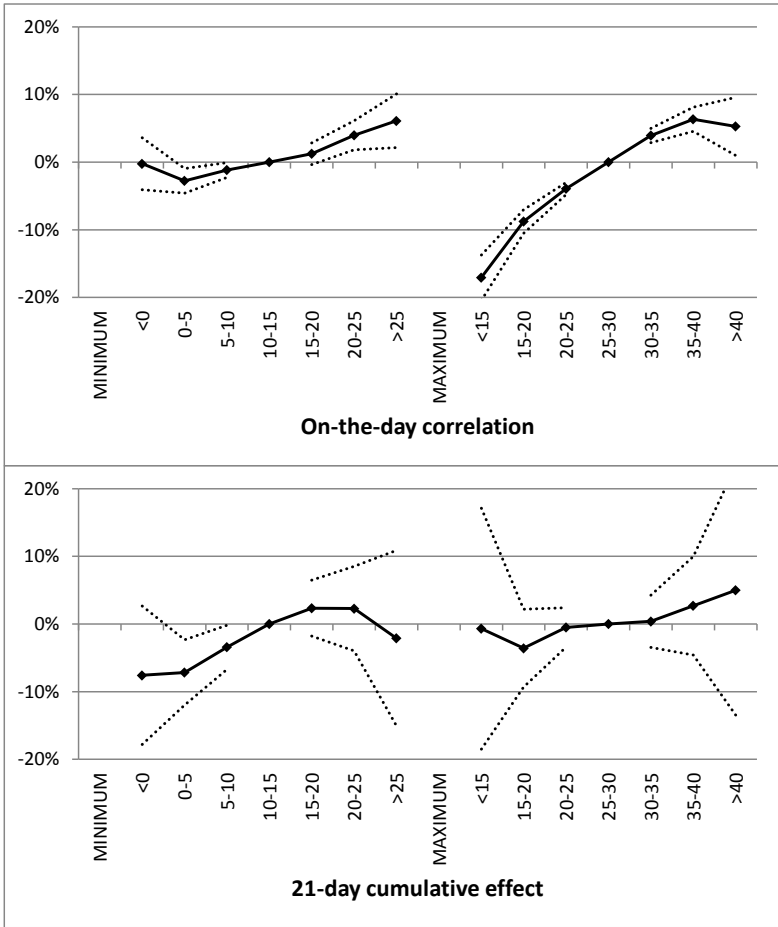
Notes: each graph corresponds to a separate regression. Results are separately displayed for weekdays (left panels) and weekends (right panels). The dependent variable is daily accusation rate as a share of the average accusation rate of each category. The independent variables are all the listed temperature bins and the amount of precipitation in the day. On the upper panels, the y-axis reports the contemporaneous effect of temperatures on accusation rates. On the lower panels, 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

5.5. Day-time vs. night-time offenses

Another important matter is whether accusations are made for offenses that occur during the day or during the night. On a very hot day, night temperatures are usually not very far from the comfort zone of the human body, at 20-25°C. Therefore, it makes a difference if additional crimes are committed at temperatures that are comfortable to the human body (at night), or if they are committed at annoyingly high day-time temperatures at around 40°C: night-time crimes are much less likely to be spurred by any psychological effect of high temperatures on irritability. On the contrary, night-time crimes could reflect that mild temperatures may increase social interactions at night and alter the usual activities of victims and criminals in a way that favours offenses.

In Figure 12, 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). On-the-day correlations show that the maximum amplitude in accusation rates caused by maximum temperatures is around 2.6 times the maximum amplitude caused by minimum temperatures (between the 0-5°C and the >25°C bins). It follows that around 28% of crimes committed during hot days would be committed at night.

Figure 12: On-the-day and 21-day cumulative effect of minimum and maximum temperatures on the daily accusation rate



Notes: the two graphs correspond to two separate regressions. However, the effects of minimum temperatures and maximum temperatures are simultaneously estimated, i.e. both are put as independent variables in the same regressions. Results are separately displayed for on-the-day correlation (upper panel) and the 21-day cumulative effect obtained with a distributed lag model (lower panel panels). The dependent variable is the 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

For comparison, in the 2016 National Survey on Victimization and Perception about Public Safety, around 28% of crimes were committed between 6pm and midnight, and 13% between midnight and 6am. Hence, weather-induced criminality might be a bit more sensitive to daytime than night-time temperatures, and evidence supports the idea that most crimes triggered by high average daily temperatures are caused by annoyingly high temperatures (or equivalently the absence of comfortably mild to cold temperatures during the day).³¹ Yet, the lower panel of Figure 11 suggests that unusually cold temperatures at night seem to bear the long-run effect of temperatures on accusations.

We have performed the same types of analysis by type of crimes and found no significant difference between the main results and most crime categories. However, the 21-day cumulative effects lost significance in most cases. Two exceptions, for which we display the results in Figure 13, are worth mentioning: the case of rapes and sexual aggressions; and the case of drug-related diseases.

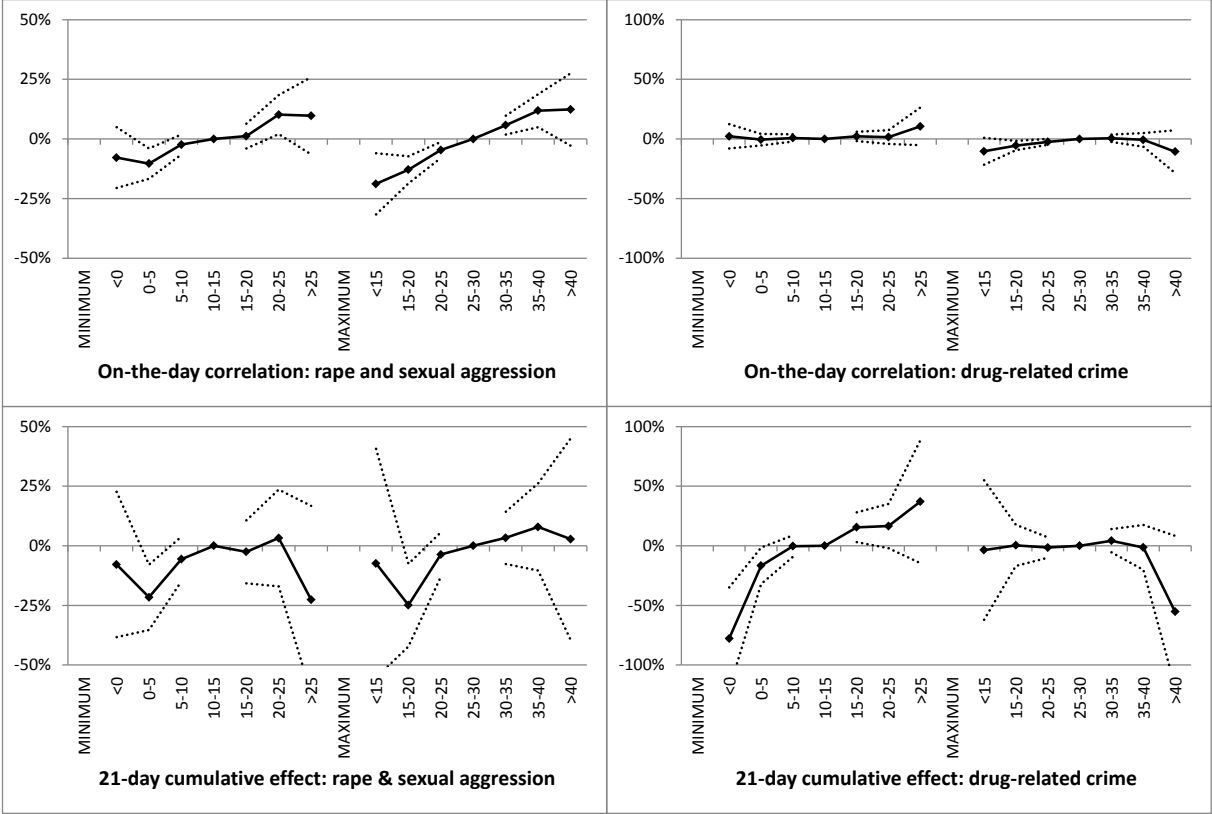
For rapes and sexual aggressions, we find that maximum temperatures have a stronger influence than minimum temperatures, as for other crimes, but this difference is attenuated. For rapes and sexual aggression, the amplitude in accusation rates caused by maximum temperatures is around 1.6 times the amplitude caused by minimum temperatures in the on-the-day correlations: around 39% of weather-related rapes and sexual aggression happen at night. Furthermore, we find statistically significant impacts at 21 days for both maximum and minimum low temperatures (minimum temperatures of 0-5°C and maximum temperatures of 15-20°C). This is consistent with the main results obtained for this category of crimes, as shown in Figure 7. The fact that cold temperatures at night might deter additional rapes suggests that the psychological effect of temperature on crime cannot be the main explanation for an increase in rapes during hot days.

For drug-related crimes, we find no effect of on-the-day temperatures for these crimes, but a longer term impact of temperatures after 21 days. This longer term impact is clear when minimum temperatures are below 0°C. It also seem to be very strong for maximum temperatures above 40°C, even though the coefficient is only statistically significant at 10%.

³¹ We have run analyses where we look at the effect of minimum temperatures and maximum temperatures separately between weekdays and weekends, and did not find any difference in the observed patterns. Hence, there seem to be no significant difference in the way maximum and minimum temperatures impact accusation levels between weekdays and weekends, even though the magnitude of the impacts changes. For the sake of concision, these analyses are not reported.

Instead of measuring here any behavioural effect, we may be measuring an effect of temperatures on the supply of drugs, since Mexico is a marijuana and opium producer.

Figure 13: On-the-day and 21-day cumulative effect of minimum and maximum temperatures on the daily accusation rate for rapes and sexual aggressions and drug-related crimes



Notes: graphs correspond to separate regressions. However, the effects of minimum temperatures and maximum temperatures are simultaneously estimated, i.e. both are put as independent variables in the same regressions. Results are separately displayed for on-the-day correlation (upper panel) and the 21-day cumulative effect obtained with a distributed lag model (lower panel panels). The dependent variable is the daily accusation rate for rapes and sexual aggressions (left panels) and drug-related crimes (right panels) 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

6. Conclusion

This paper finds a statistically significant impact of temperatures on criminal activities, consistent with previous literature. Using a distributed lag model we find strong displacement effects, 35% of the additional criminal acts performed during hot days would have occurred anyways in the following days. When breaking down the effects by types of crimes, we are certain of the additional effect of temperatures on crime for only two types of crimes: drug-related crimes; and rapes and sexual aggressions.

In terms of magnitude, we find that Mexico would experience an increase in short-term accusation rates by 3.3%, under the RCP4.5 climate change scenario by the end of the century. The impact on sexual offenses is much stronger, since climate change could increase this type of offenses by 10.6% by the end of the century.

The evidence in this paper provides additional insight on the possible reasons why temperature affects criminality. While the eventuality of a psychological effect cannot be discarded, it is strongly challenged as the only explanation of the short term correlation between temperature and criminality. The temperature–criminality relationship is linear. If excessively hot temperatures were the main factor responsible for the correlation between temperature and criminality, we should observe strong non-linearities in the relationship with effects only for the warmest temperature. Second, we find an effect of temperature on rapes and sexual aggressions. However, this effect seems to stem more from cold temperatures. This is inconsistent with the idea that heat could upset potential rapists. Finally, about 28% of weather-related crimes (and 39% of rapes) seem to be committed at night.

On the other side, we are able to show that changes in routine activities are a contributing factor to the association between weather and crime. We find that 9% of heat-related crimes occur because of heavy consumption of alcohol during hot days. Also, the extra flexibility that people have to modify their schedule during weekends explains, by itself, 17% of all heat-related crimes.

On the contrary, rational economic behaviour seems to have little explanatory power on the correlation between temperature and criminality: offenders do not commit more premeditated crimes and they are not better off by committing a crime during a hot day. In addition, a small share (9.4%) of all heat-related crimes is made of accidents.

More research is required to look at the way changes in activities during hot days may explain changes in criminality patterns, or how this phenomenon could be exploited to efficiently design policy responses against crime.

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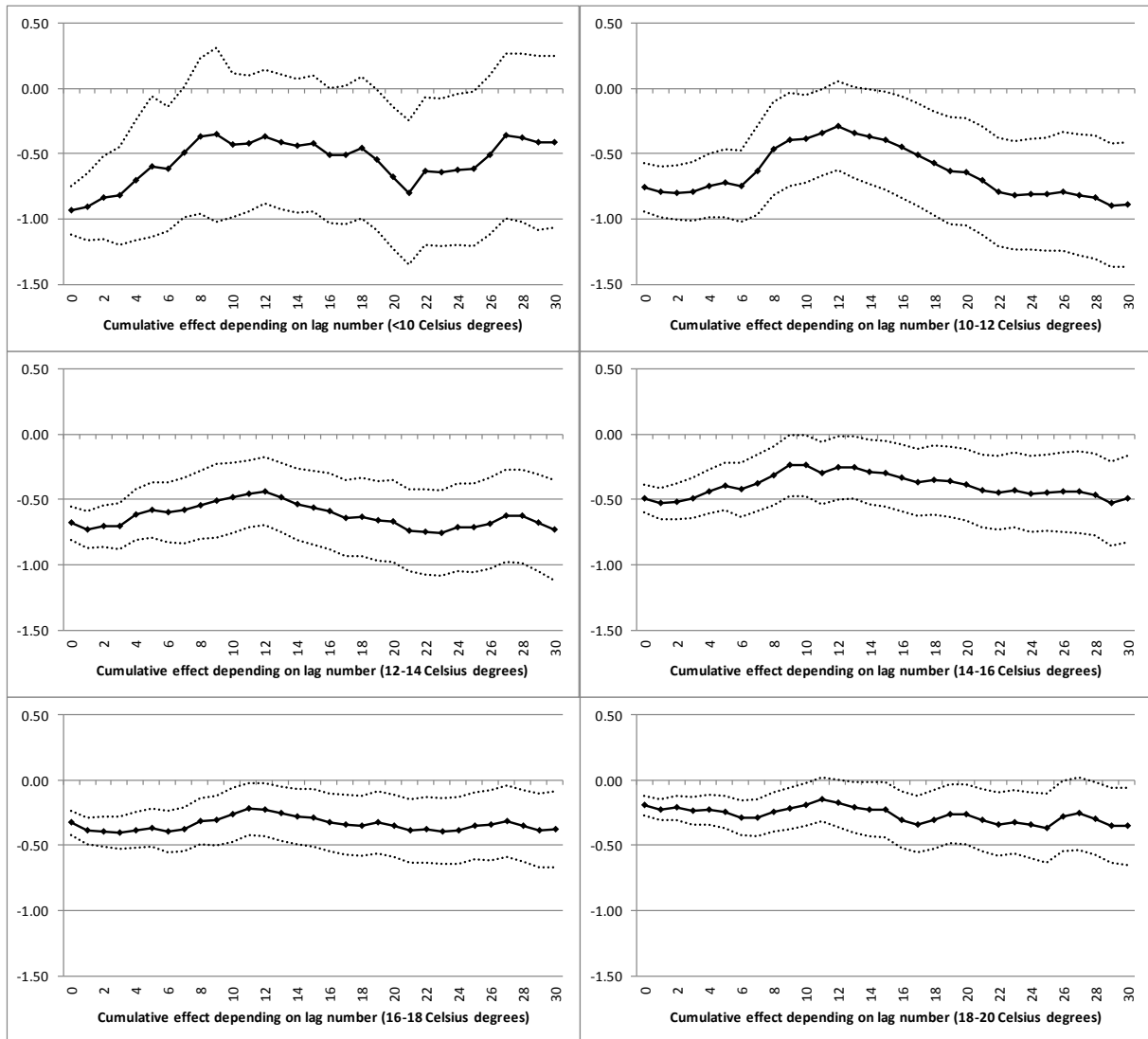
Appendices

A. Choosing the number of lags in the model

In this appendix, we are reporting the cumulative coefficient values of our main regression (for all crimes) when the number of distributed lags is modified. We have run 31 regressions in which the number of lags varies between 0 (contemporaneous model) and 30. We report the coefficient values obtained for each temperature bins in the tables below. Figure A.1 reports the results for the coefficients below the reference bin of 20-22°C. Figure A.2 the results for the coefficients above 20-22°C. All these coefficients have been extracted from the 31 same regressions.

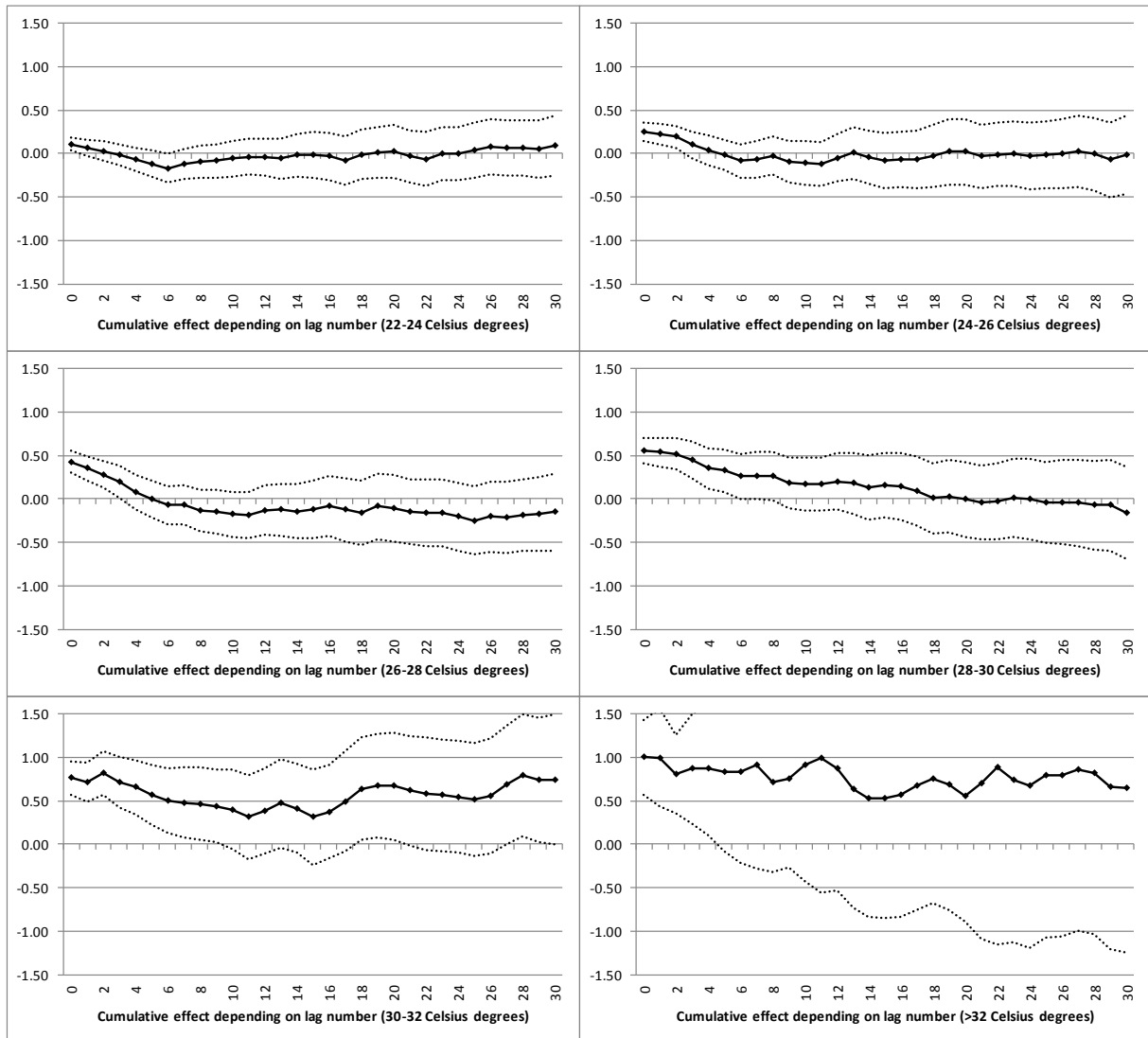
In general, the effect becomes stable after 20 days. For hotter temperatures, it seems to be monotonously attenuated, except for the 30-32°C bin, for which the point estimate increases in value after 15 days. Attenuation can be easily explained if temperatures accelerate actions and therefore displaces offenses on hot days. In the case of cold days, the (negative) effect is attenuated during the first 8-12 days, and then increases again and gain stability past 20 days. This later increase in the absolute value of the negative coefficient can be explained if the first shock reduces propensity to recidivism or if it also prevents retaliations from happening. However, we cannot be sure that an artefact of the data or econometric model is not causing it.

Figure A.1: Cumulative effect of temperature on prosecutions (all types of crimes) according to the number of lags – bins below the reference of 20-22°C



Notes: Each panel provides the coefficient estimates obtained in 31 separate regressions for a specific temperature bin below 20°C. In each regression, the dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the available temperature bins (from <10°C to >32°C and a reference bin of 20-22°C), and the amount of precipitation in the day. The number of lags included in each regression varies and is reported in the x-axis. The y-axis reports the long-run multiplier on the accusation rates and it varies with the number of lags included in each specification. 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 indicated by dashed lines for standard errors clustered at the level of municipalities. 95% confidence intervals are indicated by dashed lines for standard errors clustered at the level of municipalities.

Figure A.2: Cumulative effect of temperature on prosecutions (all types of crimes) according to the number of lags – bins above the reference of 20-22°C



Notes: Each panel provides the coefficient estimates obtained in 31 separate regressions for a specific temperature bin above 22°C. In each regression, the dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the available temperature bins (from <10°C to >32°C and a reference bin of 20-22°C), and the amount of precipitation in the day. The number of lags included in each regression varies and is reported in the x-axis. The y-axis reports the long-run multiplier on the accusation rates and it varies with the number of lags included in each specification. 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 indicated by dashed lines for standard errors clustered at the level of municipalities.

B. The contribution of rainfall and humidity

Rainfall

The results presented in the previous section only imperfectly control for precipitations. Yet, precipitations and temperatures strongly correlate and may both explain variations in the criminality rates. In this section, we address this issue and evaluate the relative importance of precipitations vs. temperatures in explaining criminality rates.

In a similar fashion as for temperature, we can estimate the contemporaneous effect of precipitation and its 20-day cumulative effect using precipitation bins. Instead of simply controlling for on-the-day precipitations as in the baseline models presented in section 4.1, we resort hereafter to 6 precipitations bins; one reference bin for days without rainfall, and five bins for days with precipitations of 0-5mm, 5-10mm, 10-15mm, 15-20mm and over 20mm. The frequency of these days in our dataset is reported in Table B.1 below.

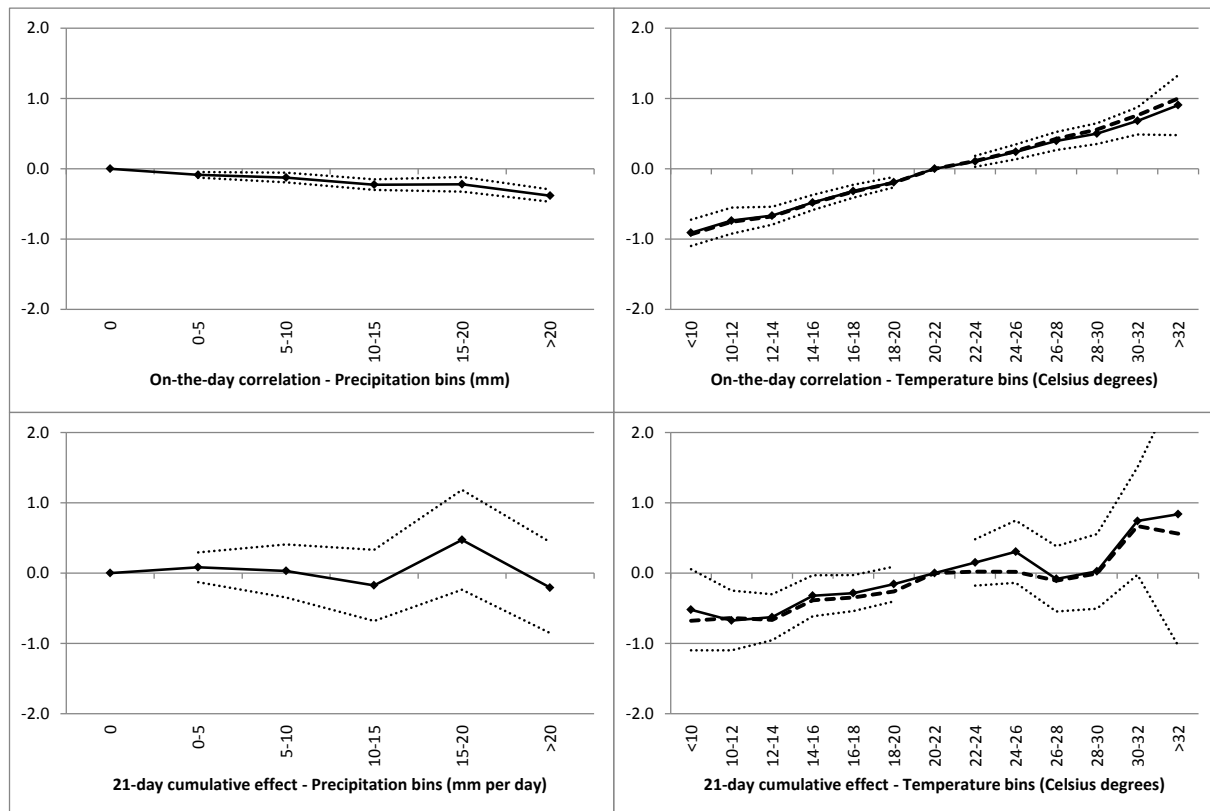
Table B.1: Days with precipitations experienced by Mexicans during a year (1997-2012)

Amount of precipitation	None	0-5mm	5-10mm	10-15mm	15-20mm	>20mm
Number of days	223.8	89.1	25.2	12.0	6.2	8.7

Notes: The Table displays the distribution of days with precipitations in Mexico across 6 precipitation-day bins. The average number of days in each precipitation bin over 1997-2012 has been weighted by population using municipality-level averages for precipitations.

Figure B.1 reports the results obtained with the contemporaneous model (upper panel) and the distributed lag model (lower panel) when these bins are included. On the left panels, we provide the results for the impact of precipitations on criminality. We find that high levels of precipitations reduce overall criminality by around 0.4 crimes per million inhabitants. This is relatively small since it represents around 6.6% of the average daily crime rate in Mexico. After 20 days, we find no persistent effect of rainfall on criminality. On the right panels, we provide the results for temperature. For comparison, these panels also display a thick dashed line that reproduces to the baseline results of section 4.2. We find no difference in the baseline estimates for temperature and the ones obtained when precipitations bins and their lags are used. Hence, precipitations of the day and previous days do not confound our baseline results.

Figure B.1: on-the-day and 21-day cumulative effect of precipitations and temperatures on the daily accusation rate for all types of crimes



Notes: The upper panel results correspond to the ones obtained with the contemporaneous model when both temperature and precipitation bins are used. Hence, the upper panel reports the results for precipitation bins (left) and temperature bins (right) from the same regression. The lower panel results correspond to the ones obtained with the distributed lag model when both temperature and precipitation bins are used. They also correspond to one single regression. Estimates for precipitation are at the left and for temperatures at the right. In both the contemporaneous and distributed lag models, the dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed precipitation and temperature bins. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. For the distributed lag model (lower panel), the y-axis reports the long-run multiplier of each temperature bin on the accusation rates. The multiplier includes on-the-day precipitation or temperature bins and 20 lags. 95% confidence intervals are indicated by thin dashed lines for standard errors clustered at the level of municipalities. In the right panels, estimates for the temperature bins are compared to baseline point estimates. The latter are displayed with a thick dashed line. The reference temperature bin is 20-22 Celsius degrees, and the reference precipitation bin is 0 (i.e. no precipitation during the day). 355,306 groups and 27 observations per group.

Our general conclusion is that temperatures have a stronger influence than precipitations on criminality. This is in line with the evidence from Mares (2013), who find an impact on temperature but no impact of precipitations on criminality in Saint Louis, Missouri. Our general feeling is that precipitations rarely occur all day long, and that victims and offenders may easily delay some activities by up to a couple of hours when it rains.

Another factor may be that time spent outdoors only constitutes a small fraction of the time spent during a day. While the impact of precipitations cannot be felt indoors, outdoor temperatures are likely to strongly influence indoor temperatures in Mexico. The country is ill-

equipped with heaters and air-conditioners: between 1998 and 2010, heating and cooling appliance ownership among households was respectively 3.2% and 12.4% on average.³²

In addition, we searched for differences in the impact of precipitations on criminality by type of crimes. We found no persisting impact of precipitations on crime for any crime category. We however found that the on-the-day correlation between crime and precipitations was apparently stronger for violent crimes than for other types of crimes, e.g. thefts and damages to property. Results by type of crime are quickly synthesised in Table B.2 which reports the coefficient value obtained for days with precipitations above 20mm when using the contemporaneous model.

Table B.2: On-the-day correlation between daily crime rates by type of crimes and daily precipitations over 20mm.

Type of crime	>20mm
All crimes	-6.6% ***
Homicide	-8.5% *
Injury	-12.3% ***
Rape and sexual aggression	-12.7% ***
Possession of weapons	-7.8% ***
Property damage	-4.7% ***
Drug-related crime	-4.6% **
Theft (excl. car theft)	-2.1% **
Car theft	+8.6%
Manslaughter	-7.7%
Kidnapping	-5.9%

Notes: We report the results for the >20mm precipitation bin and the contemporaneous model when run on all types of crimes, and then on ten categories of crimes separately. Each estimate therefore comes from a different regression. The dependent variable is the daily accusation rate, normalised by the average daily accusation rate of each category. Even though we only report the results for the >20m m precipitation bin, each model includes all the previously mentioned precipitation and temperature bins. The regressions also include municipality by-month by-year fixed effects and are weighted by the square root of the population in each municipality. Statistical significance at 10%, 5% and 1% are respectively mentioned with one, two and three stars (*) and have been obtained with standard errors clustered at the level of municipalities. The reference precipitation bin is 0 (i.e. no precipitation during the day).

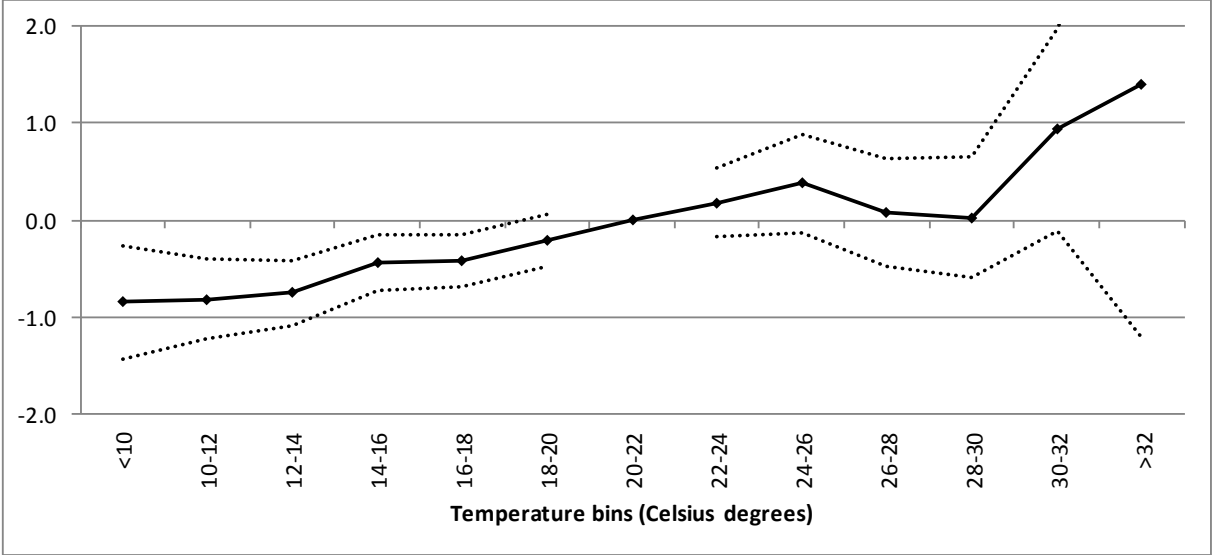
Humidity

In an additional specification, we include evaporation levels and their lags in a distributed lag model where we have included the temperature bins, their lags, and precipitation levels (in mm) and their lags as well. This model allows assessing the effect of humidity on criminality. We find no statistically significant impact at 20 days. We report below the relationship that we

³² Own calculation based on the results of the *Encuestas Nacionales de Ingresos y Gastos de los Hogares* (1998, 2000, 2002, 2004, 2005, 2006, 2008, 2010).

found between temperature and crime after controlling for both precipitations and humidity. It is similar to the main specification.

Figure B.2: 21-day cumulative effect of temperature on accusations (all types of crimes) after controlling for humidity and precipitations



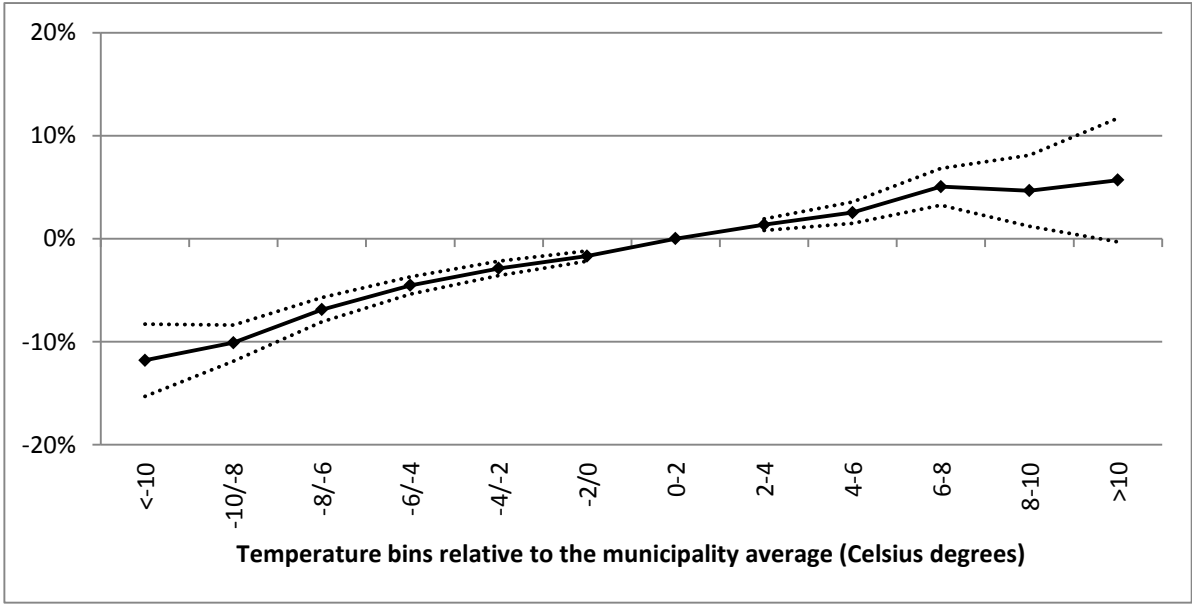
Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins, the amount of precipitation in the day, its 20 lags, and the evaporation level of the day, and its 20 lags. The y-axis reports the long-run multiplier 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

C. Relative temperature bins

Due to acclimatization, the effect of temperatures on criminality could differ from one location to another. Below, we calculate deviations from the average temperature in each location to construct relative temperature bins with a 2°C window. These include deviations between -10°C and +10°C with respect to the average of each municipality. The average temperature in each municipality is obtained by averaging all daily temperatures over 1997-2013.

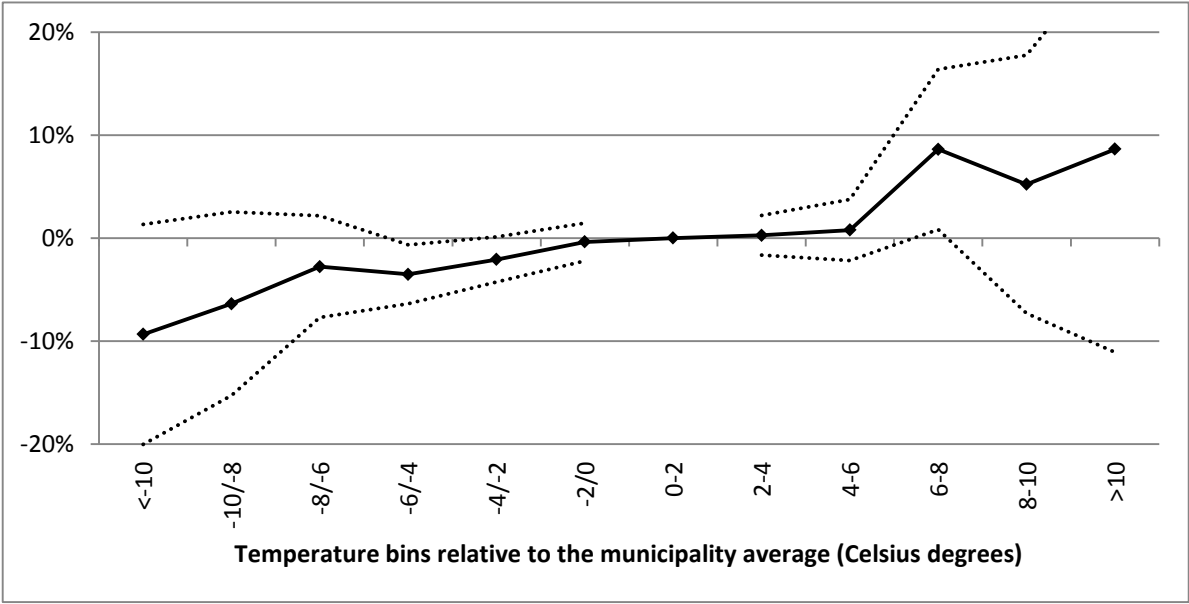
The results of the contemporaneous model are provided in Figure C.1 and the results with the distributed lag model are displayed in Figure C.2. Results with relative temperature bins show a similar linear increase in criminality. However, the impact is in fact smaller in magnitude and results are less efficient. The attenuated impacts and efficiency losses makes us think that absolute temperatures are a better reflection of true impacts.

Figure C.1: correlation between on-the-day temperature and accusations (all types of crimes) when using relative temperature bins



Notes: The dependent variable is daily accusation rate as a share of the average accusation rate in Mexico. The independent variables are temperature bins relative to the municipality average between 1997 and 2013 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 0-2 Celsius degrees above the municipality average. 370,094 groups and 30.1 observations per group.

Figure C.2: 21-day cumulative effect of temperature on accusations (all types of crimes) when using relative temperature bins

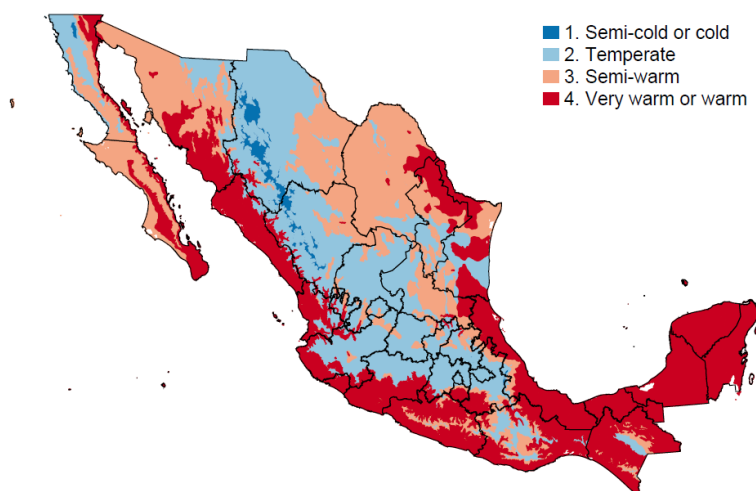


Notes: The dependent variable is daily accusation rate as a share of the average accusation rate in Mexico. The independent variables are temperature bins relative to the municipality average between 1997 and 2013 and the amount of precipitation in the day. The y-axis reports the long-run multiplier of each relative 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 0-2 Celsius degrees above the municipality average. 370,094 groups and 30.1 observations per group.

D. Effects by climate regions

Mexico is a large country with very diverse climates. The temperature-criminality relationship could be different across these climates. The INEGI provides a detailed map of Mexico with a typology of 21 climates. We have simplified this typology and broken it down into 4 climate categories (see Figure D.1): very warm and warm (covering very dry, dry, semi-dry, humid and semi-humid regions that are also very warm and warm); semi-warm; temperate; and semi-cold or cold (covering respectively all semi-warm, temperate, semi-cold or cold regions independently of humidity).

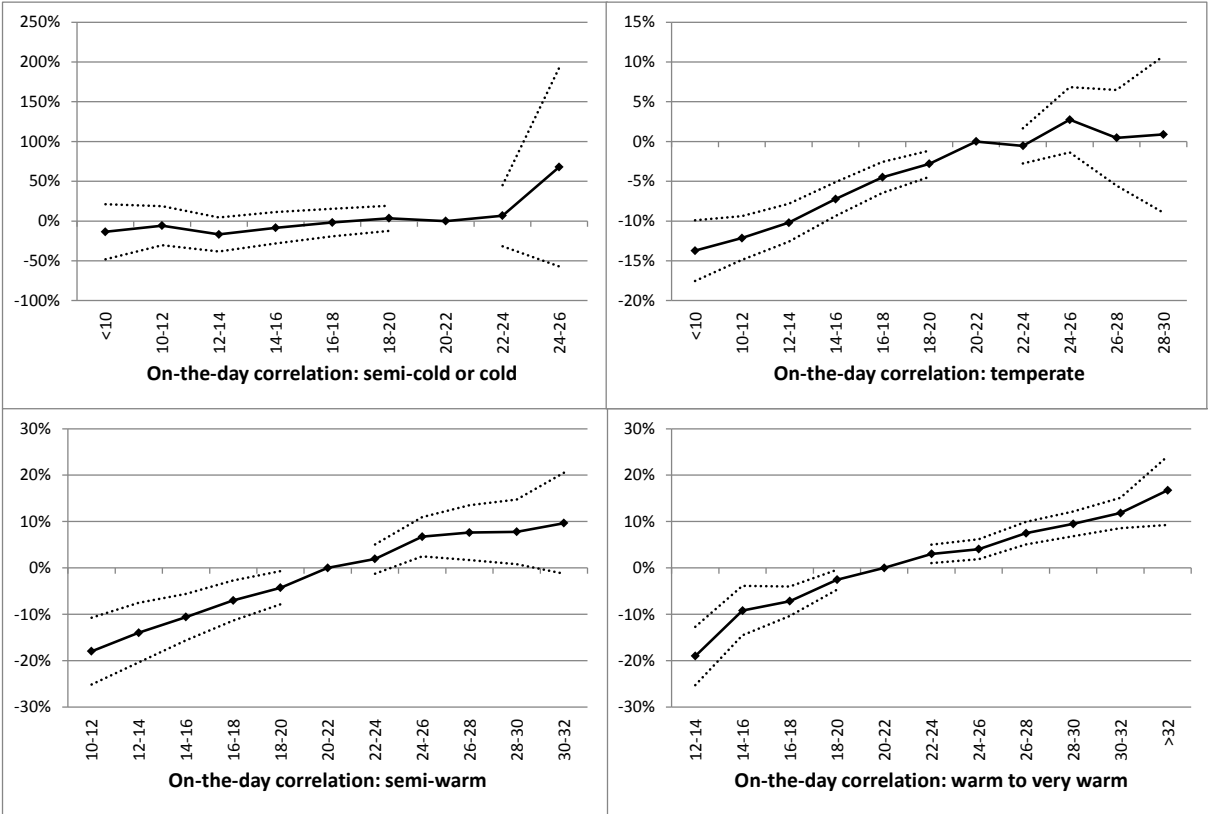
Figure D.1: Map of Mexico distinguishing between warm, semi-warm, temperate and cold climates



We have matched the boundaries of the 2,456 Mexican municipalities with the boundaries of our four climatic categories.³³ We then ran the contemporaneous and distributed lag models separately for the municipalities falling in each climate. Results (for all crimes) are displayed in Figure D.2 for the contemporaneous model and in Figure D.3 for the distributed lag model. All temperature bins have been used in the models, but their display has been truncated when the number of days falling in one category was too small for a given climate (e.g. $<10^{\circ}\text{C}$ for hot areas, or $>32^{\circ}\text{C}$ in cold areas). This was done to ease the readability of the graphs. In general, we find that an increase in temperature correlates with an increase in criminality, even though results can be imprecise. However, results are not conclusive for cold regions, which is not surprising considering their small amount in Mexico.

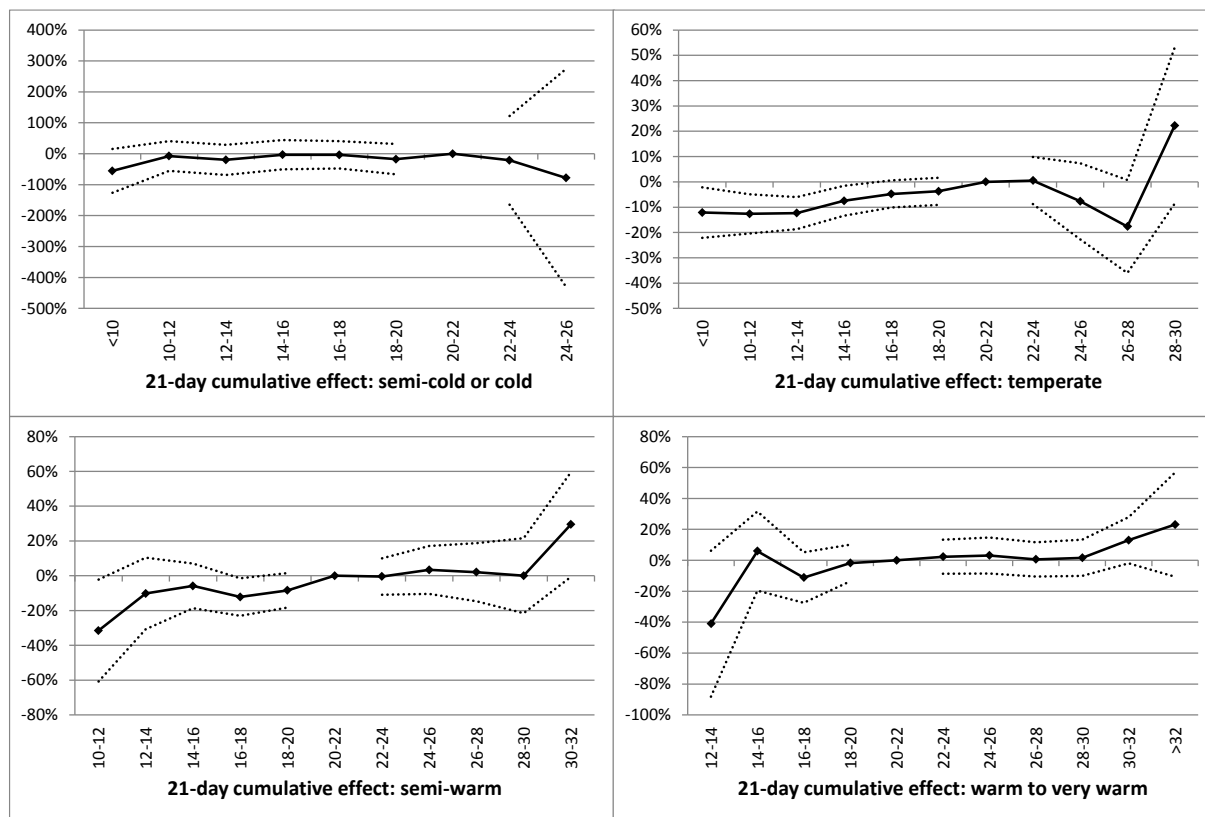
³³ The map of INEGI defines municipalities as a set of data points that produce a polygon. Our matching strategy assigns a climate to each point of the polygon that corresponds to the boundaries of a municipality. For each municipality, we calculate the number of delimiting data points that fall in a given climate. If this number exceeds half the total number of data points that constitute the boundary of the municipality, we consider that this municipality belongs to this climate.

Figure D.2: correlation between on-the-day temperature and accusations (all types of crimes) by climate region



Notes: The dependent variable is daily accusation rate as a share of the average accusation rate in each Mexican climate region. The independent variables are all available temperature bins and the amount of precipitation in the day. We however display only the temperature bins that did not display unrealistic results due to lack of days at the extreme of the distribution of specific climates. 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

Figure D.3: 21-day cumulative effect of temperature on accusations (all types of crimes) by climate region

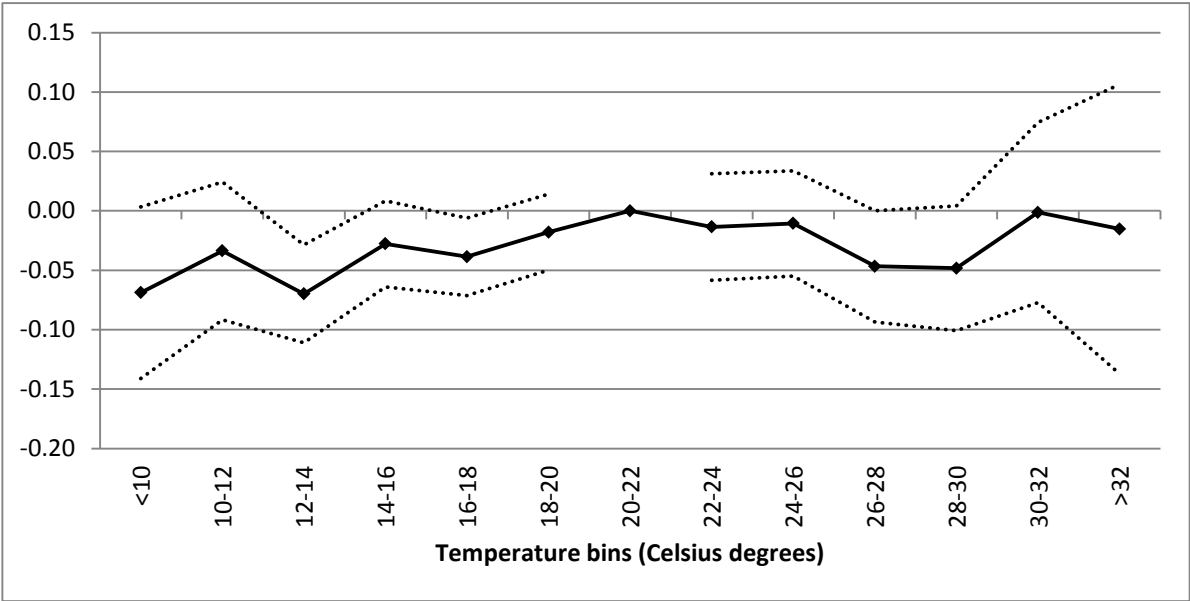


Notes: The dependent variable is daily accusation rate as a share of the average accusation rate in each Mexican climate region. The independent variables are all available temperature bins and the amount of precipitation in the day. We however display only the temperature bins that did not display unrealistic results due to lack of days at the extreme of the distribution of specific climates. The y-axis reports the long-run multiplier of each relative 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 indicated by dashed lines for standard errors clustered at the level of municipalities. 95% confidence intervals are indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

E. Dividing the sample in two periods

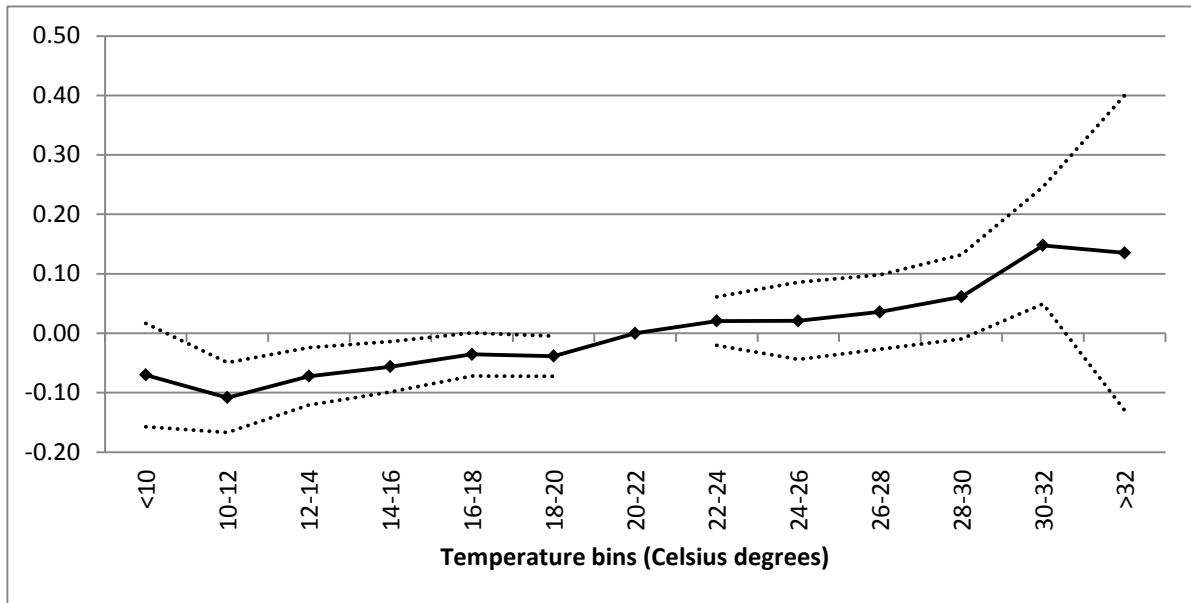
Below, we report the results of the distributed lag model when the sample period has been split in two. Figure E.1 displays the results for 1997-2004 and Figure E.2 displays the results for 2005-2012. Results for 1997-2004 are inefficient and only weakly capture the correlation between temperature and crime. Results for 2005-2012 are much clearer. The difference in the efficiency of the results obtained is likely to stem from an increase in data quality over time.

Figure E.1: 21-day cumulative effect of temperature on accusations (all types of crimes) as obtained for 1997-2004



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. 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 E.2: 21-day cumulative effect of temperature on accusations (all types of crimes) as obtained for 1995-2012

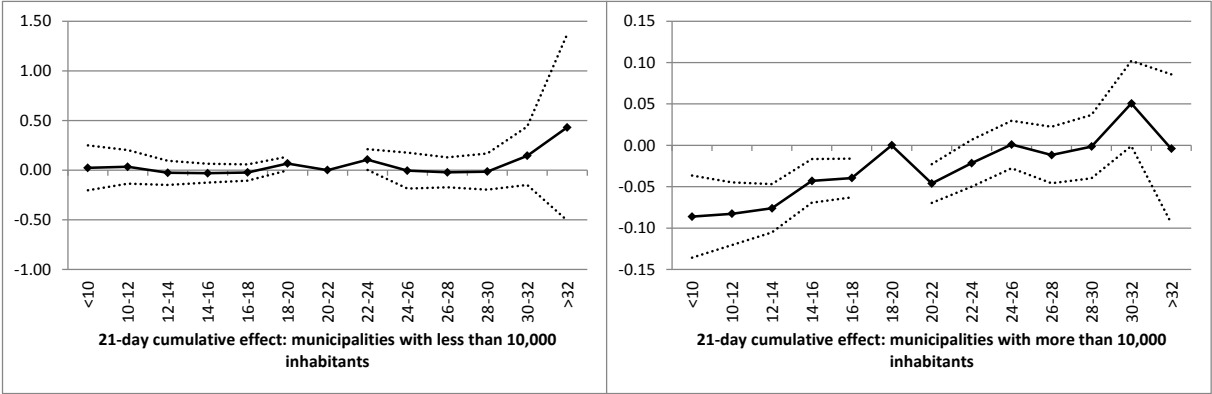


Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants. The independent variables are all the listed temperature bins and the amount of precipitation in the day. The y-axis reports the long-run multiplier of each temperature bin on the accusation rates. The multiplier 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

F. Effect according to the size of municipalities

We have run the distributed lag model separately for municipalities with less and with more than 10,000 inhabitants (see Figure F.1 below). We find that the relationship only holds for municipalities with more than 10,000 inhabitants, consistent with the fact that criminality tends to be an urban phenomenon.

Figure F.1: 21-day cumulative effect of temperature on accusations (all types of crimes) according to the size of municipalities



Notes: The dependent variable is the daily accusation rate in crimes per 1,000,000 inhabitants, in municipalities with less than 10,000 inhabitants in the left panel, and in municipalities with more than 10,000 inhabitants in the right panel. 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 indicated by dashed lines for standard errors clustered at the level of municipalities. The reference bin is 20-22 Celsius degrees.

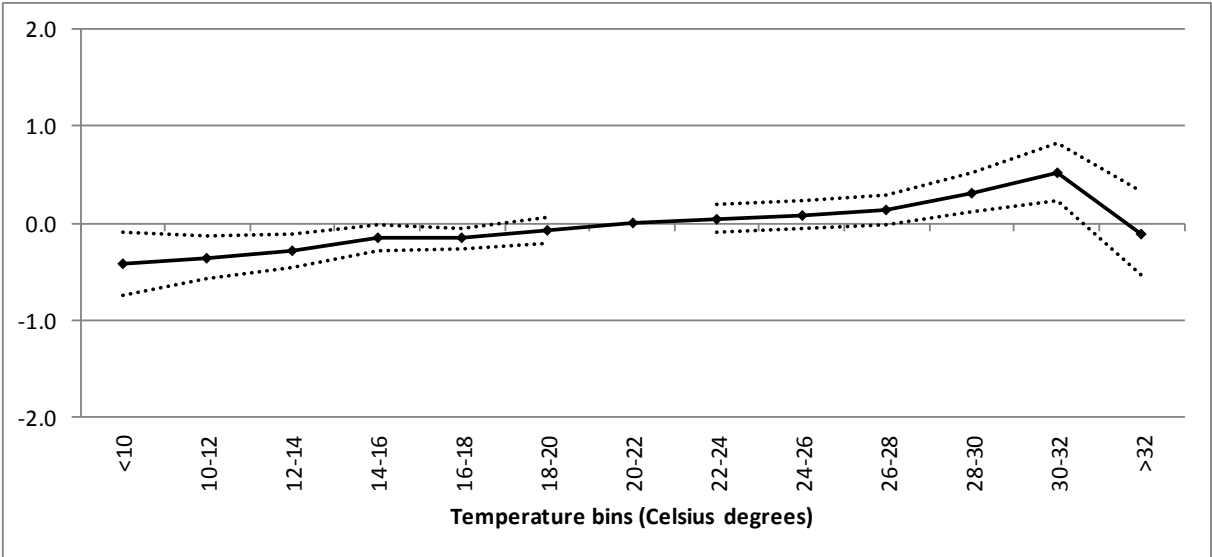
G. Changing the structure of the fixed effects

In this Appendix, we use different structures for the fixed effects. In the base specification, we have used fully interacted, municipality-by-year-by-month fixed effects. This restrains the comparison of mortality effects to days within the same month of the year within a given municipality and disregards the fact that changes in temperature may affect seasonal patterns, and in turn criminality. Above all, we could underestimate the criminality impacts of direct exposure to temperature in very cold or very hot months by comparing very cold days with already cold days, and very hot days with already hot days within a month.

We find that relaxing the controls has no strong influence on our results. We have adopted three different specifications, which all give similar results. Amplitude is a bit lower but very close, with a difference between cold and hot days of about 0.1 accusations per million inhabitants.

In Figure G.1, we display the results with municipality by year fixed effects and separate month fixed effects. Apart from this, nothing is changed to the base model. The dependent variable is the daily accusation rate including all sorts of crimes and the dependent variables are the temperature bins, their 20 lags, and the precipitations level.

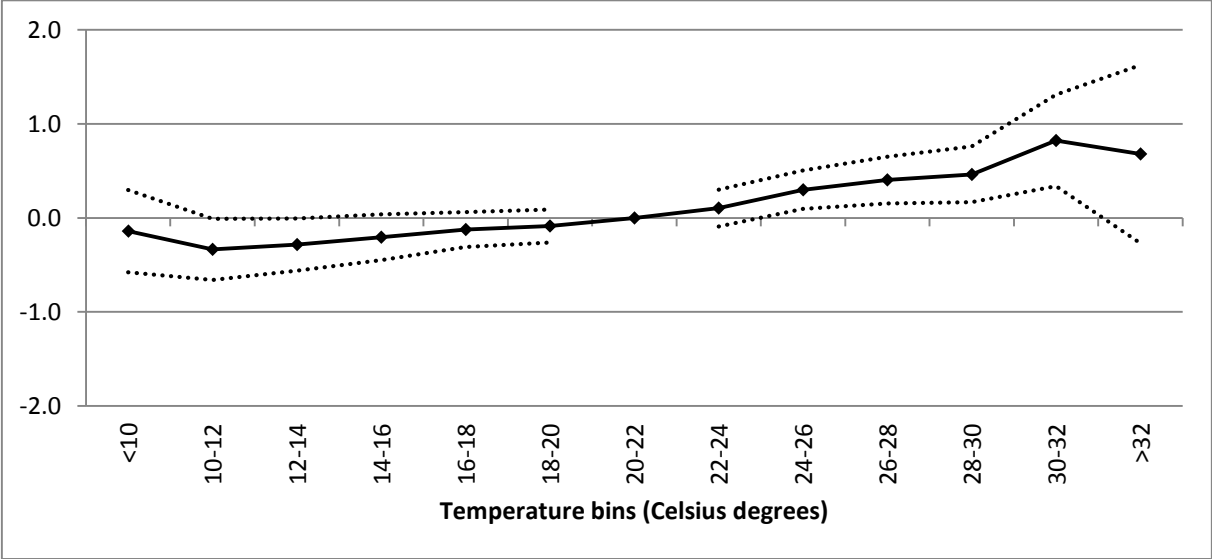
Figure G.1: 21-day cumulative effect of temperature on accusations (all types of crimes) with unicity by year fixed effects and separate month fixed effects



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 regression also includes municipality by-year fixed effects and month fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are 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.

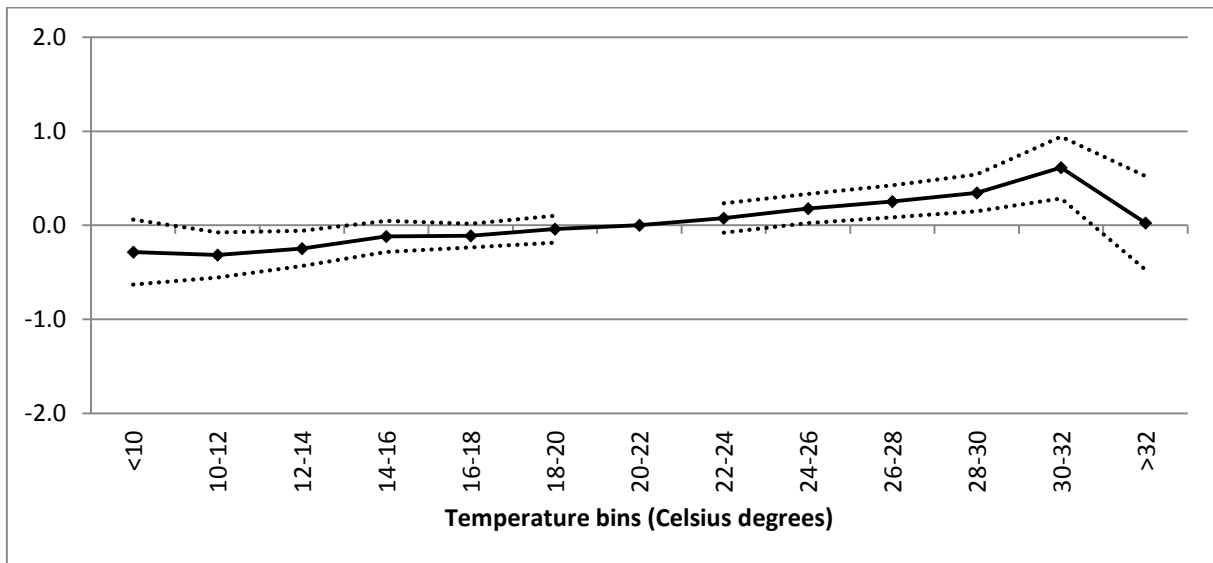
In Figure G.2, we have used municipality by month fixed effects and separate year fixed effects. In Figure G.3, we include separately municipality fixed effects, year fixed effects and month fixed effects.

Figure G.2: 21-day cumulative effect of temperature on accusations (all types of crimes) with unicity by month fixed effects and separate year fixed effects



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 regression also includes municipality by-month fixed effects and year fixed effects and are weighted by the square root of the population in each municipality. 95% confidence intervals are 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 G.3: 21-day cumulative effect of temperature on accusations (all types of crimes) with separate municipality fixed effects, month fixed effects and year fixed effects



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 regression also includes municipality fixed effects, year fixed effects and month fixed effects. They are weighted by the square root of the population in each municipality. 95% confidence intervals are 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.