

## **Economic and Non-Economic Factors in Violence: Evidence from Organized Crime, Suicides and Climate in Mexico**

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*Abstract:* Organized intergroup violence is almost universally modeled as a calculated act motivated by economic factors. In contrast, it is generally assumed that non-economic factors, such as an individual's emotional state, play a role in many types of inter- personal violence, such as "crimes of passion." We ask whether economic or non- economic factors better explain the well-established relationship between temperature and violence in a unique context where intergroup killings by drug-trafficking organizations (DTOs) and "normal" interpersonal homicides are separately documented. A constellation of evidence, including the limited influence of a cash transfer program as well as comparison with both other DTO crime and suicides, indicate that economic factors only partially explain the observed relationship between temperature and violence. We argue that noneconomic psychological and physiological factors that are affected by temperature, modeled here as a "taste for violence," likely play an important role in causing both interpersonal and intergroup violence.

**Keywords:** violence, climate, income, psychology, suicide

**JEL Codes:** O1, Q51, Q54

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# 1 Introduction

To date, economic models of violence treat interpersonal and intergroup violence as different phenomena. Instances of interpersonal violence, such as assault and murder, are generally thought of as “crimes” that may have either an economic or emotional motivation—assaulting an individual in order to expropriate their assets is clearly economic, whereas “crimes of passion” are a commonsense notion reflecting emotional factors. In contrast, violence between groups of individuals is almost always modeled as a strategic calculation where the economic costs of conflict are weighed against potential gains. In many cases, this decision to focus on economic factors is well-motivated and generates sharp predictions that often agree with data.<sup>1</sup> Here we propose that noneconomic factors could also play an important role in causing intergroup violence, alongside known economic factors. This idea narrows the gap between models of interpersonal violence and intergroup violence, and accordingly we augment a standard model of strategic conflict by including noneconomic factors already accounted for in models of interpersonal violence. We then demonstrate that this richer model is better able to account for observed patterns of violence in Mexico, a unique context where we are able to study both interpersonal and intergroup homicide in a common setting and where levels of violence are high.

In an ideal experiment designed to test whether noneconomic factors influence intergroup violence, one might manipulate the psychological state of all the individuals within a group and observe whether the overall level of violence between that group and nearby groups changed. That experiment is clearly neither feasible nor desirable, so instead we leverage an emerging “stylized fact” in the environment-economy literature: the frequently observed positive relationship between changes in temperature and human conflict (Hsiang et al., 2013). This temperature-conflict relationship has now been documented across diverse geographic settings and for many types of human conflict, ranging from institutional collapse to civil war, riots, and crime, and estimate effect sizes in these studies are often large. For instance, recent meta-analyses report average effect sizes of a roughly 10% increase in intergroup violence per  $1\sigma$  increase in temperature (Burke et al., 2015). This implies a large historical role for temperature variation in shaping conflict risk, and an even larger potential role for future climate change in shaping these outcomes, given the anticipated  $>4\sigma$  increase in temperature expected across much of the tropics over the next century.

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<sup>1</sup>See, for example, Collier and Hoeffler (1998), Miguel et al. (2004), Angrist and Kugler (2008), Berman et al. (2011), Besley and Persson (2011), Dube and Vargas (2013), among others.

Why might changes in temperature induce violence and conflict, and what can this tell us about the broader economic and noneconomic underpinnings of violence? Economists often interpret the temperature-conflict relationship as an income effect: hotter temperatures and lower rainfall are known to lower incomes, particularly in agricultural areas, and this in turn could temporarily lower the opportunity cost of participation in violence. In an early study, Miguel et al. (2004) provide empirical evidence that rainfall shocks that lower economic growth also increase the likelihood of civil war in Sub-Saharan Africa. Chassang and Padró-i-Miquel (2010) explain this result by developing a bargaining model in which violence occurs when a shock to economic productivity temporarily lowers the opportunity cost to violence, but does not affect the future value of winning the contest.

This economic hypothesis about group-level violence, however, seems incomplete in that it does not account for the observed response of individual-level violence to daily or even hourly variations in temperature, as income is unlikely to change over these short periods (Jacob et al., 2007, Card and Dahl, 2009, Larrick and et al, 2011, Ranson, 2014). Vrij et al. (1994) offer perhaps the clearest case, where police officers were observed utilizing more violence during a training exercise when temperature in the room was manipulated to be hotter, which clearly was unrelated to economic incentives. In another laboratory experiment, which is unfortunately poorly documented, Rohles (1967) reports,

“When [participants] were subjected to high temperatures in groups of 48, there was continual arguing needling, agitating, jibing, fist-fighting, threatening, and even an attempted knifing. At lower temperatures or in small groups, this behavior diminished.”

Thus, while inter-personal violence is often conceived in economics as an action with private costs and benefits that also imposes costs on others (Becker, 1968), and which agents may apply rationally to affect the allocation of resources (Donohue and Levitt 1998, Chimeli and Soares 2017, Castillo et al. 2018), it is also understood that noneconomic factors may play a role and are likely partially responsible for generating the temperature-violence link.

Given that most instances of group-level violence are, at the most basic level, implemented by individuals, this then suggests a potential additional role for noneconomic factors in intergroup violence. Consider the group member on the front lines of a conflict who is personally implementing violence on behalf of a group’s strategic objectives. There are many decision points where non-economic psychological factors likely play an important role

in this individual’s decision making, with the individual having some discretion in exactly how much violence to employ when contact with the opponent actually occurs. If the agent enjoys violence they may employ more of it, and if the agent dislikes violence they may employ less. Should there be many ways for these types of noneconomic factors to influence the overall level of violence employed by individuals in the group, then these noneconomic factors must be considered important elements in intergroup conflict.

We propose a unified framework in which both interpersonal and intergroup violence are influenced by economic and noneconomic factors, although their relative influence may differ (making it ultimately an empirical question). We expand a standard economic model of violence to include a pure consumption value of violence to the aggressor, which we model as a positive or negative input into utility depending on an individual’s “taste for violence.”<sup>2</sup> Introducing this single noneconomic factor and allowing it to respond positively to temperature, as indicated by prior analyses, substantially improves the ability of the model to account for observed patterns of intergroup violence.

We then test multiple hypotheses generated by this unified model in Mexico, a context where exceptional levels of violence by drug-trafficking organizations (DTOs) motivated law enforcement to gather separate data on intergroup homicides. This allows us to observe variation in comparable group-level and individual-level acts of violence, i.e. homicides in both cases, in a single context where geographical, political, and institutional factors can be “held fixed.” This provides a unique opportunity to compare the effect of temperature on both interpersonal and intergroup violence without this comparison being confounded by these contextual differences that usually differ between studies.<sup>3</sup> Such comparisons allow us to consider whether these two types of violence share a common noneconomic mechanism.

Consistent with earlier meta-analyses, we show that higher monthly temperatures have

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<sup>2</sup>In a similar vein, Tauchen et al. (1991), Farmer and Tiefenthaler (1997), Bowlus and Seitz (2006), and Aizer (2010) explain domestic violence as expressive behavior that provides positive utility to some men. Their partners tolerate it in return for higher transfers. Card and Dahl (2009) adopt this interpretation of family violence as motivation to consider the role for emotional cues (or “visceral factors”) in precipitating violence. They use unexpected losses in football games as the trigger for emotional cues. A key contribution here is to extend this framework beyond domestic violence and to introduce these psychological factors into the rapidly growing literature on intergroup conflict. Blattman et al. (2017) provide experimental evidence on the role non-cognitive skills and preferences play in shaping violence.

<sup>3</sup>Hsiang et al. (2013) compare results from 60 studies and find that the average effect of temperature on interpersonal violence differs substantially from the effect on intergroup violence. However, each study only examined one form of violence and none were from comparable contexts (e.g. civil war in African countries vs. cases of domestic abuse in a town in Australia), so it is difficult to draw strong inferences from any cross-study differences.

a positive and significant effect on both killings by drug-trafficking organizations (DTOs) and “normal” homicides in Mexico. Effects in both cases are contemporaneous, large in magnitude, and generalizable across regions in Mexico. We find that a one standard deviation increase in temperature is associated with a 28% increase in drug-related killings and 5% increase in regular homicides.

We next use a variety of approaches to look directly for evidence of an economic mechanism that might explain these results. We find that such a mechanism can only partially explain patterns in DTO killings, and it has almost no explanatory power in the case of general homicides. For instance, changes in temperature have no comparable effect on non-violent and clearly economic crimes committed by DTOs, such as extortion and car theft, which we would expect to respond similarly to temperature if both were caused by a single mechanism. Similarly, random variation in the level of government social assistance through the large scale Progresa/Oportunidades program has limited effect in dampening the effect of high temperatures on group conflict, growing season temperatures matter little for harvest season violence, and other measures of economic conditions and inequality have limited predictive power in explaining the temperature-violence relationship.

We then ask whether psychological factors better explain the link between temperature and violence. Because inducing experimental variation in these factors is not possible, our approach is to ask whether patterns in the temperature response of intergroup violence mirrors the response of an outcome known to be heavily influenced by psychological factors: suicide. By introducing data on suicides in Mexico, we layer a third form of violence (intrapersonal violence) onto our two parallel data sets on interpersonal and intergroup violence in this single context. We show that suicides also respond strongly to variation in temperature, and that the pattern of this response closely matches what is observed for group-level violence across numerous dimensions: the response is linear, contemporaneous, common across regions, not mediated by observable economic factors or Progresa/Oportunidades, and only barely affected by growing season temperatures. Because suicide is strongly linked to mental illness and depression in the medical literature, and because evidence (including laboratory studies) link high temperatures to psychological responses that govern aggressive and violent behavior, we consider it a “benchmark” phenomena and interpret this pattern-matching exercise as evidence that psychological factors likely play an important role in temperature’s effect on group violence.

In addition to our primary contribution on the potential role of psychology in intergroup

violence, our work also contributes to the rapidly growing literature linking climate and conflict (Burke et al., 2015). We do this by adding two novel outcomes to the “spectrum of violence” known to be affected by climatic events (Figure 1): gang killings and suicides. Gangs are smaller and less organized than armed militias but larger and more organized than spontaneous groups, such as mobs, both of which have been previously linked to the climate. Suicides have been largely unexplored in relation to climate in the economics literature. By further expanding and filling in this spectrum of social phenomena affected by climate, this work further strengthens our confidence and understanding that climatic conditions play a fundamental role in shaping the peacefulness of modern societies (Hsiang et al., 2013). Furthermore, by providing evidence on the factors mediating the temperature-conflict link, our work contributes to a broader understanding of how we might manage the potential societal impacts of a warming planet. Unfortunately for this particular setting, our results suggest that economic interventions might have little success in mitigating the impacts of future warming on violence.

The next section discusses some background and non-economic factors in violence. Section 3 offers a simple theoretical framework that builds on previous research to highlight and operationalize the role of non-economic factors. Section 4 presents our data and discusses our empirical strategy. In Sections 5, 6, and 7 we present and discuss our main set of results. Finally, Section 8 offers some conclusions.

## **2 Understanding Violence**

### **2.1 Drug trafficking in Mexico**

Mexico has experienced a large increase in violence in the last decade, in large part due to the activities of drug trafficking organizations and the government’s response to these activities. Sophisticated organizations trafficking illegal drugs from Mexico to the U.S. first appeared in the 1990s (Grillo, 2012) but have since grown in size and sophistication, and DTOs now constitute a powerful industry that earns between 14 and 48 billion USD annually (U.S. State Department, 2009). These organizations also carry out other criminal activities including extortion and kidnapping, especially in recent years (Rios, 2014). The exact number of DTOs operating varies by year, but it is generally agreed that they rose from 6 in 2007 to approximately 16 in 2010 (Guerrero, 2012a). Many of these new organizations are factions

of older groups, an event that tends to occur after leaders are arrested or killed as a result of conflicts within and between organizations.<sup>4</sup>

Accompanying the large increase in DTOs was a large escalation of violence beginning in 2007, which has since claimed over 50,000 lives (Dell, 2015) and which has been the focus of much media and academic attention. Following the presidential election of 2006, president Felipe Calderón declared war on drug trafficking organizations. Shortly after this event, crackdowns spread through the country, and violence escalated to unprecedented levels (see Merino 2011, Guerrero 2011b, and Escalante 2011). Several factors have been offered as causes of this escalation: (1) Felipe Calderón’s strategy against organized crime, i.e. direct crackdowns and captures of DTO leaders (Guerrero 2010, Calderón et al. 2015, Chaidez 2014, Dell 2015), (2) U.S.–Colombia efforts to reduce drug flows between both countries, a supply shock that affects drug markets in Mexico (Castillo et al., 2018), and (3) exogenous movements in the international price of corn, which is the main staple crop in Mexico and whose price affects the opportunity cost of joining the drug industry (Dube et al., 2016). The relative contribution of each of these factors is, however, a matter of ongoing debate among scholars. To our knowledge, this paper is the first to link DTO violence to climate shocks.

## 2.2 Non-economic factors in violence

A large body of research has dissected the logic for violence and documented the role that economic factors can play (Miguel et al., 2004, Angrist and Kugler, 2008, Berman et al., 2011, Besley and Persson, 2011, Dube and Vargas, 2013).<sup>5</sup> This work would also seem to provide a *prima facie* explanation for the now well-documented role that changes in temperature appear to play in instigating violence and human conflict (Hsiang et al., 2013, Burke et al., 2015), given that changes in temperature are also known to induce variation in both agricultural and non-agricultural incomes (Hsiang, 2010, Dell et al., 2012).

Accumulating scientific evidence, however, also points toward an important role for phys-

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<sup>4</sup>In 2008, for example, the Sinaloa’s leader was captured and, as a consequence, this organization split. Right after this event, a war between *Sinaloa* cartel and *La Familia Michoacana* began. The state of Guerrero, where both cartels operated in previous years, was the site for most of the violence associated with this fight (Guerrero 2012b and Rios 2013). Guerrero (2011a) discusses the issue of DTO fractionalization in greater detail. See Table A.1 for characteristics of DTOs.

<sup>5</sup>See Appendix A.1 for a brief review of the literature estimating the negative consequences of violence.

iological and psychological factors in explaining certain types of human violence, and importantly (for our purposes) also the potential for temperature to shape these non-economic factors. For instance, the psychological roots of *intrapersonal* violence – i.e. suicide – have been well documented, and the role of temperature in this particular type of violence as well as in interpersonal human aggression have been explored since at least the 1930s.<sup>6</sup> While scientific understanding of temperature regulation in the human body remains imperfect (e.g., Hammel 1974, Werner 1980, Cooper 2002, and Mekjavic and Eiken 2006)), there is growing evidence that neural structures are directly involved in this process (Benzinger, 1970, Morrison et al., 2008, Ray et al., 2011). This is important because particular neurotransmitters that have been shown to participate in body temperature regulation – in particular, serotonin – have also been linked to mood, emotion, and range of important human behaviors (National Institutes of Health, 2011, Lovheim, 2012). For serotonin specifically, there is growing consensus that decreased serotonergic neurotransmission in the brain may be an important neurobiological deficit that leads to aggressive behavior (Edwards and Kravitz, 1997, Seo et al., 2008). Thus there appears to be support in the medical literature for a physiological link between temperature and violent behavior: when ambient temperature increases, serotonin levels decrease, with attendant effects on impulsive and aggressive behavior.

Recent studies provide evidence that economic factors are unlikely to fully explain the temperature-violence gradient. For example, Garg et al. (2018) find a limited role for harvesting behavior. They estimate the effects separately for weekdays and weekends, when alcohol consumption is likely to be higher, and compare the effect of temperature on domestic versus non-domestic violence. They find that the effects are partially mitigated by Progresa cash transfers and are stronger where air conditioning penetration is lower. Cohen and Gonzalez (2018) also exploit daily weather and criminal activity data from Mexico and implement a similar estimation strategy as Garg et al. (2018). They find a positive and linear contemporaneous relationship between temperature and criminal activity. They find strong effects on violent crimes, small effects on property damage and thefts and drug related crimes, and long-lasting effects on accusations of rape and sexual aggression. To disentangle mechanisms they look into the circumstances of weather-induced crimes; they find that 90% are intentional, nearly 10% are due to the increased consumption of alcohol, 17% are due to

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<sup>6</sup>See Appendix A.2 for a review of the literature estimating the relationship between temperature and suicide and the seasonality of suicides. For example, Baron and Bell (1976) show that individuals were more likely to behave aggressively towards others when ambient temperature was higher. Burke et al. (2018) estimate the causal impact of temperature on suicides in Mexico and the U.S. and provide evidence of an increase in aggressiveness in online networks when temperature is abnormally high.



changes in time allocation during weekends, and 28% are committed at night.<sup>7</sup>

Results from these contemporaneous studies complement ours in pointing to the role of non-economic factors in explaining the impact of temperature on violence. In contrast to them, our goal is to understand whether non-economic factors play a role in *group-level* violence in general, and more specifically to compare the extent to which they mediate the observed responsiveness of both interpersonal and group violence to changes in temperature.

### 3 Theoretical Framework

To understand how these non-economic physiological and psychological factors might complement the standard way in which economists have understood the logic of violence, we develop a simple model of violence that builds on the framework in Chassang and Padró-i-Miquel (2010) but incorporates a new potential mechanism affecting how high temperature can lead to violence. In the model, two sides,  $i \in \mathcal{I} = \{1, 2\}$ , decide whether or not to engage in costly violence and redistribution when bargaining fails. The players cannot commit to not engage in conflict for an infinite number of periods, where time is indexed by  $t$ . Each player combines  $l$  units of labor, which we normalize to  $l = 1$ , with productivity  $\theta_t$ .

The sides can engage in two possible actions, namely being violent or peaceful,  $a \in \mathcal{A} = \{V, P\}$ , which they choose simultaneously. Both groups want to maximize their economic output at the end of the game. If one player attacks first, then it has a first strike advantage and captures all of the opponent's output with probability  $p > 0.5$ . An attack costs both the aggressor and defender a fraction  $c \in (0, 1]$  of output. If both agents choose to attack simultaneously, they each win with probability 0.5. Additionally, we assume there is common knowledge of a non-rival psychological consumption value for violence, which is a function of temperature  $\tau$ , i.e.  $\gamma_t = \gamma_t(\tau)$  with  $\frac{\partial \gamma_t(\tau)}{\partial \tau} > 0$ , and  $\gamma_t(\tau) \in \mathbb{R}$ . If  $\gamma_t(\tau) > 0$  then the player gains positive utility from violence. We omit the argument,  $\tau$ , in setting up the model, but return to it when discussing its role in explaining violence through different channels.

We consider a dynamic model where the two groups interact in every period  $t$ . There is at most one round of fighting and the winning group reaps the benefits of its prize into the future. If there is no attack in the current period, then each agent expects a peaceful

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<sup>7</sup>Recent evidence suggests that the temperature-violence relationship is also unlikely to be fully explained by economic factors in India (Blakeslee et al., 2018).

continuation value  $V^P$ , which is the discounted ( $\delta$ ) per capita utility of expected future consumption from the player's initial assets and which captures expectations of future values of all parameters. Similarly, if one side wins, then they have a continuation value of winning  $V^V$  which is the per capita expected utility from consumption of both their initial assets and the assets that they capture from their opponent.

We can write the condition for peace, incorporating the psychological consumption value for violence,  $\gamma_t$ , as:

$$\underbrace{\theta_t + \delta V^P}_{\text{value of peace}} > \underbrace{p(2\theta_t(1-c) + \delta V^V) + \gamma_t}_{\text{value of violence}} \quad (1)$$

In interpreting the above, a player finds it privately beneficial to choose peace if the per capita value of consuming all output with initial assets plus discounted expected utility under peace  $\delta V^P$  (left hand side) exceeds the expected utility of consumption from both the player's original assets and captured assets, less expenditures on the conflict, plus the expected continuation value  $p\delta V^V$  and the psychological consumption value of violence (right hand side).

We then rearrange (1) so that the condition for peace becomes:

$$\theta_t(1 - 2p(1 - c)) - \gamma_t > \delta[pV^V - V^P] \quad (2)$$

where the left side of the inequality is the marginal value of peace in the current period weighed against the discounted marginal expected utility from attacking on the right side.

In considering the mechanism, the economics literature on conflict has focused on the impact of temperature on  $\theta_t$  in explaining violence. The left hand side of (2) shows that if economic conditions are sufficiently bad (i.e.,  $\theta_t$  is sufficiently close to zero), and ignoring psychological factors for the moment, conflict will occur. For example, a drought has a contemporaneous effect on productivity, which reduces the current opportunity cost of conflict more than it alters the continuation value of peace (note that  $\theta_t$  does not feature in the right hand side).

In the model above, we highlighted the importance of the non-rival psychological consumption value for violence,  $\gamma_t$ . If climatic conditions influence  $\gamma_t$  by increasing the utility (or decreasing the psychological cost) of acting violently, i.e.,  $\frac{\partial \gamma_t(\tau)}{\partial \tau} > 0$ , then these changes

may increase the likelihood that (2) does not hold and violence occurs.<sup>8</sup> That said if the sides have a general dislike of violence ( $\gamma_t(\tau) < 0$ ), then there will be less conflict than that predicted by economic factors alone.

## 4 Empirical Framework

### 4.1 Data and descriptive statistics

We collected monthly information on reported homicides and suicides at the municipality level from Mexico’s Bureau of Statistics (INEGI) for the period between January 1990 and December 2010.<sup>9</sup> This data corresponds to the universe of homicides and suicides officially reported. To minimize confounding with the Mexican Drug War, we split this time frame in a “pre-war” period between January of 1990 and December of 2006, and a “war” period between January of 2007 and December of 2010. Our empirical analysis focuses on the pre-war period when analyzing homicides and suicides, and on the war period when studying drug-related killings (henceforth DTO killings). In the pre-war period there were a total of 218,970 homicides and 55,206 suicides, with a monthly per municipality average (standard deviation) of 0.44 (2.49) and 0.11 (0.77), respectively.

The empirical analysis uses the total number of deaths per 100,000 inhabitants as the dependent variable, as is standard in the literature (see Hsiang et al. 2013). Figure 2 shows the time series and cross sectional variation for DTO killings and homicides for all municipalities. Table 1 presents descriptive statistics for these variables in the two periods of interest. We observe an average of 0.98 homicides and 0.21 suicides per 100,000 inhabitants per municipality-month in the pre-war period, and an average of 0.83 homicides and 0.26 suicides between years 2007 and 2010. The variation in these variables is substantial, as shown by the within standard deviations of 5.23 and 1.93 for homicides and suicides respectively. At the state level, some have as many as 6.2 homicides per 100,000 inhabitants – an

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<sup>8</sup>An alternative is to introduce a physiological mechanism discussed in the literature on cognition. A number of studies have reported the importance of environmental factors, such as heat, on cognitive performance (Mackworth 1946, Fine and Kobrick 1978). Fine and Kobrick (1978) found that heat has significant effects on the ability of individuals to perform complex cognitive tasks involved in artillery fire and in which they were trained. In the above model, we can think of this effect as an additive error term,  $\epsilon$ , whose variance increases with temperature, in which the players simply err in making their decision to fight, a decision they might not make at lower temperatures.

<sup>9</sup>In this section we discuss the main variables to be used in the empirical analysis. Additional data, and the corresponding descriptive statistics, can be found in Appendix B.

extremely high homicide rate.<sup>10</sup>

Monthly data on DTO killings was compiled by a committee with representatives from all ministries that are members of the National Council of Public Security in Mexico. This data is available for the period starting in December 2006 to December 2010 at the municipality level. The characteristics of each killing occurring in this period were analyzed by the committee to determine whether it corresponded to a killing that was linked to some drug trafficking organization in Mexico. There were a total of 34,436 DTO killings between 2007 and 2010, with an average (standard deviation) of 0.29 (3.94) killings per municipality-month. The variation in this variable is striking, with roughly 20% of state-months having zero killings and some having as many as 452.<sup>11</sup> Panel B in Table 1 presents descriptive statistics for this variable. DTO killings rates are roughly half the size of homicides rate during this period, and the distribution is more skewed.

Figure 2 shows time averages (weighted by population) for DTO killings (2007-2010) and homicides (1990-2006) in all municipalities in Mexico. Homicides seem to be decreasing during this time period, something analyzed in more detail by Escalante (2011).<sup>12</sup>

Finally, we construct monthly temperature and precipitation for each municipality-month using data from Willmott and Matsuura (2014). This is a gridded dataset with monthly information for cells of size 0.5 degrees.<sup>13</sup> In order to transform this gridded dataset into a municipality-level dataset, we take the average of temperature and the sum of precipitation

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<sup>10</sup>Monthly rate of 6.2 homicides in our dataset implies a rate of 74.4 homicides per 100,000 per year. This is an extremely high homicide rate. To put this in perspective, the most violent country in the world in 2012 (Honduras) had a rate of 90.4 homicides per 100,000 inhabitants, and the second most violent (Venezuela) had a rate of 53.7. Figure A.1 also compare rates of these types of violence to the US. Homicide rates in Mexico were twice as high in Mexico compared to the US in 2006 and have been rising ever since. Suicide rates, however, are substantially higher in the US. Finally, and not surprisingly, organized crime killings are far higher in Mexico, a difference that has again been increasing since 2006.

<sup>11</sup>Our results are robust to excluding states with a large upward trend in DTO killings, i.e. Baja California, Chihuahua, Durango, Guerrero, Sinaloa, and Tamaulipas. Results are also robust to including state specific trends, as discussed below.

<sup>12</sup>Dube and Ponce (2013) study violence in Mexico before 2006. These authors find that an expiration that relaxed the permissiveness of gun sales caused an increase of roughly 239 deaths annually in municipalities close to the relevant state borders.

<sup>13</sup>“Gridded weather datasets use interpolation across space and time to combine available weather station data into a balanced panel of observations on a fixed spatial scale or grid. This approach deals with the problem of missing observations at a given station or missing data because a station does/did not exist at a particular location. (...) Each “grid” approximates a weather measure for the spatial unit by interpolating the daily station data while accounting for elevation, wind direction, rain shadows, and many other factors.”, (Auffhammer et al., 2013).

for all pixels inside the polygons that represent Mexican municipalities. Municipalities during our sample period have an average temperature of 20 degrees celsius, with a standard deviation of 5.0 degrees celsius. However, after removing municipality, year, and month fixed effects, following our econometric specification (below), the standard deviation of this variable at the municipality-month level is approximately 2.8 degrees celsius. Figure A.4 presents the distribution of temperature by period.

## 4.2 Econometric strategy

To estimate a causal link between temperature and our dependent variables of interest, we follow Deschenes and Greenstone (2007), and the preferred method employed by Hsiang et al. (2013) (see Dell et al. 2014 for a review). Accordingly, we control for unobservable time-invariant factors at the municipality level that could be correlated with both average temperatures and violence, unobserved shocks common to all municipalities within in a state in a given year, and average seasonal patterns in both temperature and violence. Specifically, in our preferred specification we estimate the following regression:

$$y_{nsmt} = \beta \text{Temp}_{nsmt} + \delta \text{Precip}_{nsmt} + \xi_m + \lambda_t + \zeta_n + \varepsilon_{nsmt} \quad (3)$$

where  $y_{nsmt}$  is the number of DTO killings, homicides, or suicides per 100,000 inhabitants in municipality  $n$ , state  $s$ , month  $m$ , and year  $t$ ;  $\alpha$  is a constant term;  $\xi_m$  and  $\lambda_t$  are full sets of month and year fixed effects;  $\zeta_n$  is a full set of municipality fixed effects, respectively;  $\text{Temp}_{nsmt}$  is average temperature, measured in degrees celsius;  $\text{Precip}_{nsmt}$  is total precipitation, measured in thousands of millimeters; and  $\varepsilon_{nsmt}$  is an error term clustered at the state level. In robustness tests, we also estimate equation (3) adding state-specific linear time trends (to account for differential state-level trends in, for instance, policies to fight violence), or replacing the month-of-year fixed effects  $\xi_m$  with state-by-month-of-year fixed effects  $\xi_{sm}$ —to account for state specific seasonality in violence and temperature; there is some evidence, for instance, in seasonality in suicides in particular (Ajdacic-Gross et al., 2010). Our main coefficients of interest are  $\beta$  and  $\delta$ , which are identified through natural exogenous fluctuations in weather conditions, conditional on location and time effects. After demonstrating that our results are robust across specifications, we report results from (3) for most of the analyses.

We also present temperature response functions using the number of days in a set of bins

and estimates of the effect of leads and lags of temperature on violence. The latter exercise is important for a number of reasons. First, there may be temporal displacement: it may be the case that an event that would have occurred in the future anyway is triggered earlier by extreme climatic conditions. With full displacement, the contemporaneous and lagged effects would be of similar magnitude but opposite in sign, and there would be no overall effect of climate on violence. Even with partial displacement, a sole focus on contemporaneous impacts could overstate the total effect of a change in temperature.

Lags can also be useful in identifying delayed or persistent effects. For example, a negative temperature shock during the growing season in an agricultural based economy may increase violence during the harvest season when income for the farming season is realized (a delayed effect), or a weather shock could trigger a conflict that persists for multiple periods.

Finally, the temporal pattern of response to temperature shocks could also shed light on the mechanism underpinning the response. Given that we are using monthly data, certain income effects (such as the agricultural income story just told) might be expected to show up with a few-month lag. Physiological responses, on the other hand, would be expected to show up contemporaneously, given the immediacy with which the body’s thermoregulatory function is employed.

To explore these temporal dynamics, we estimate the following regression:

$$y_{nsmt} = \sum_{k=t-6}^{k=t+6} \beta_k \text{Temp}_{nsmk} + \sum_{k=t-6}^{k=t+6} \delta_k \text{Precip}_{nsmk} + \xi_m + \lambda_t + \zeta_n + \varepsilon_{nsmt} \quad (4)$$

where all variables are defined as before, and we include six monthly leads and six lags of temperature. Our interest lies in the parameters  $\beta_k$  and  $\delta_k$ . In particular, a violation of our identification assumption would be reflected in any of the coefficients  $(\beta_{t+1}, \dots, \beta_{t+6})$  being statistically different from zero, i.e., future climate variation should not be correlated with past violence. Persistent effects or displacement would translate into the coefficients  $(\beta_{t-6}, \dots, \beta_{t-1})$  being statistically different from zero.

## 5 Climate and Violence

Figure 3 displays non-parametrically the relationship between temperature and our measures of group and interpersonal violence (DTO killings and homicides, respectively), with

municipality-, year-, and month-fixed effects partialled out of both the dependent variables and temperature. The  $x$ -axis is interpreted as the average temperature in a given municipality-month, and the  $y$ -axis is interpreted as deviation from that municipality-month average in the corresponding measure of violence. For reference, a one standard deviation in the temperature variable within a municipality corresponds to 2.8 degrees celsius. The thick line corresponds to the non-parametric conditional mean, while the lighter color depicts the 95 percent confidence interval. These temperature response functions are clearly upward sloping for both variables, and appear roughly linear through most of the temperature support.

Table 2 presents regression results from estimating equation (3) under various sets of fixed effects. To facilitate the interpretation of these coefficients, and comparison across outcomes and studies, standardized effects are presented in square brackets, which we express as percentage change in the dependent variable per one standard deviation change in the climate variable of interest. The first three columns show results using DTO killings per 100,000 inhabitants as dependent variable, and the last three show corresponding results for homicides in the pre-2007 period.

Several interesting patterns emerge. First, we observe a positive and significant effect of temperature on both intergroup and interpersonal violence, a result that is robust across all specifications. The magnitude of these estimates varies across columns, but is particularly large for DTO killings: in our base specification (Column 1), we find that a  $1\sigma$  increase in temperature in a given month is associated with a 28% increase in the rate of DTO killings. This result is robust to inclusion of either state-specific time trends or state-month FE. Given the large level of killings during this period – over 34,000 DTO killings over the 2007-2010 period – a 22% increase is large in both percentage and absolute terms. The roughly 5% effect for homicides is smaller in magnitude, but is also substantial given again the high homicide rate in the country over the period (285,000 total homicides during the 1990-2010 period). We find no statistically significant effect of precipitation on either intergroup or interpersonal violence, and in all specifications we can confidently reject large effects of precipitation. The effects of climate on violence in Mexico appear to occur through temperature.

Anticipating our more formal treatment of treatment-effect heterogeneity below, in Figure A.2 we explore whether there are apparent spatial patterns in the responsiveness of DTO killings or homicides to temperature. We estimate state-specific responses of violence to temperature, and display these in the figure as the ratio of the state-specific estimate to the

pooled country-wide estimate reported in Columns 1 or 4 of Table 2 – i.e.  $\frac{\hat{\beta}_{s,y}}{\hat{\beta}_y}$ . Although there is some apparent variation in estimated effects across states, results are remarkably homogenous: point estimates are positive in all states for DTO killings and positive in all but one state for homicides, the ratio of state-specific estimates to pooled estimates is near unity for most states, and in the case of DTO killings, in only 4 out of 32 states do confidence intervals on state-specific estimates not contain the pooled estimate (equivalent to 13% of states, only slightly higher than what sampling variability alone would predict). For homicide, there does appear to be somewhat more variation in effect sizes across states, with 38% of state-specific confidence intervals not containing the country-wide estimate (8 estimates are significantly larger than the pooled estimate, 4 are smaller). Below we explore more extensively whether economic factors can explain this heterogeneity.

Finally, as shown in Figure 4, our benchmark estimates of how intergroup and interpersonal violence respond to temperature in Mexico are remarkably consistent with other reported temperature-conflict estimates from the literature (none of which were from Mexico). Figure 4 plots the distribution of standardized coefficients from an earlier meta-analysis (Hsiang et al., 2013), showing in the bottom two panels either the 24 studies from Hsiang et al. (2013) that examined intergroup conflict or the 12 studies that examined interpersonal conflict. The estimated effects for DTO killings and homicides from Mexico lie within the expected distributions for intergroup and interpersonal conflict, respectively.

## 6 Economic Factors

### 6.1 Other DTO criminal activities

Can economic factors explain the strong and robust relationship between temperature and violence in Mexico? In the absence of a way to experimentally manipulate the income of drug-trafficking organizations, we approach the problem indirectly from a number of angles. Our first approach is to observe whether other (plausibly) economically-motivated DTO criminal activities also respond similarly to temperature. Besides killings, drug trafficking organizations are also known for other criminal activities such as kidnappings, extortion, and car thefts. These crimes appear to have a clear economic motivation, and so if economic factors such as income are what is mediating how DTO violence responds to temperature, a similar temperature response might be evident in these similarly economically-motivated



activities.

We assembled administrative data on the monthly occurrence of kidnappings, extortion, and car thefts during the period between January of 2007 and December of 2010. Unfortunately these data is not available at the municipality level but at the state level instead. Table 3 present the estimates of interest, and include our main results on DTO killings and homicides for comparison. Strikingly, we do not observe any significant relationship between temperature and these other criminal activities. In fact, estimated coefficients have a negative sign in the case extortions and kidnappings, although not statistically significant, and the effect on car thefts is fairly small and not statistically significant. Temperatures appear to increase violent crime but not these other criminal activities.

## 6.2 Income, unemployment, and inequality

Our second approach is to look directly at whether municipality-level income variables mediate the temperature-violence relationship. To do this, we augment equation (3) and include an interaction term between temperature and various measures of income or income inequality at the municipality level. In particular, we examine interactions with municipality-level income and with the municipality-level Gini coefficient.

Results are shown in Table 4. We find little evidence that these municipality-level measures of income mediate the temperature-violence relationship. For the per-capita income measure, the interaction has the expected sign for DTO killings, but is statistically insignificant and the coefficient is small: a one standard deviation increase in log GDP per capita, which we think of as being a fairly large increase in income, attenuates the effect of temperature on DTO killings by 13 percent ( $-0.008/0.063 \approx 0.13$ ). The interaction in the homicide regression is also statistically insignificant, and is of the opposite sign than expected.

Another economic measures is economic inequality, measured here with time-invariant municipality-level Gini coefficients (constructed by Jensen and Rosas 2007). Income inequality has been argued in the literature to be an important driver of violence and conflict in different settings. But as shown in the table, it does not appear to substantially affect how either intergroup or interpersonal violence respond to temperature in Mexico. In the case of DTO killings, a one standard deviation in inequality decreases the effect of temperature on violence by roughly 12 percent, but it is not statistically significant.

Finally, we explore the mediating influence of two other variables that are typically

correlated with income: the adoption of air conditioning (typically positively correlated with income), and municipality-level average temperature (negatively correlated with income across countries as well as across Mexican states). Air conditioning could be viewed as an income-related adaptation, and as such could represent an alternative pathway through which higher incomes could break the link between temperature and violence. The “mediating” effect of higher average temperatures on the response of violence to temperature deviations is perhaps more subtle. On the one hand, states with higher average temperatures might be more adapted to hot temperatures, and thus less effected by additional increases in temperature. On the other hand, if the underlying temperature response is non-linear (as in agricultural productivity), then additional heat exposure on top of an already high mean should induce a more negative response.

Results of including air conditioning penetration or average temperature as interaction variables are show in rows 3 and 4 of Table 4. Neither variable appears to explain how violence responds to temperature: coefficients in both cases are small in magnitude and statistically insignificant. Thus we find little additional evidence of income-induced adaptation (at least through the AC channel), nor strong evidence that hotter average temperatures reduce impacts (through adaptation) or worsen them (through non-linearities).

### **6.3 Quasi-experimental variation in monetary transfers**

Our third approach to studying the role of economic factors is to exploit the roll-out of a large-scale cash transfer program, PROGRESA, which induced quasi-experimental variation in income across much of Mexico during our study period. PROGRESA is a very large program, with a budget of approximately 133 million USD in 1997 (roughly 0.03% of GDP), which has since expanded to almost 5 billion USD in 2010 (roughly 0.5% of GDP). We observe bimonthly transfers to every municipality during the period between January 1998 and December of 2009 from administrative sources. Importantly, cash transfers in this program targeted women with children, and so we cannot be certain the extent of income variation that the program induced among the population likely to participate in DTO related activities (young men).<sup>14</sup> Nevertheless, we augment our main regression equation by including the logarithm of PROGRESA transfers as an additional independent variable, and

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<sup>14</sup>This is one reason our results likely diverge from Fetzer (2014), who shows that the relationship between monsoon shocks and insurgent conflict is largely eliminated in India after the introduction of a public employment program (NREGA) that guaranteed wage labor to everyone.

an interaction term between this variable and temperature.

Results from this exercise are presented in Table 5. First, transfers alone seem to decrease the rate of DTO killings, although the effect is relatively modest and not statistically significant: an *increase* of 10 percent in transfers *decreases* killings by 0.1 percent. The effect is smaller in the case of homicides and not statistically significant. Regarding the interaction term, the coefficient is also negative and marginally significant in the case of DTO killings, which suggests transfers also modestly decrease the local sensitivity of violence to temperature, but it is again a fairly precise estimated zero in the case of homicides.

In Figure A.5 we also incorporated an interaction term between leads and lags of PROGRESA transfers and temperature and we reach the same conclusion: transfers modestly decrease DTO killings, but only contemporaneously, these have no effect on homicides, and the interaction term is marginally significant and negative only for the case of DTO killings. Overall, it seems that even large monetary transfers to poor households in a very high-profile anti-poverty social assistance program can only slightly reduce levels of intergroup violence and have no effect in the case of interpersonal violence – again subject to the caveat that we cannot be sure how much of this income reached those individuals likely to participate in DTO activities.

#### 6.4 Harvest and growing season effects

Our final approach to exploring the role of economic factors is to study whether temperature shocks during economically critical periods have a greater impact on violence compared to shocks at other times in the year. In particular, as a substantial portion of the Mexican labor force continues to earn their living in agriculture (roughly 15%), and as agricultural income has been one of the most salient variables emphasized in the literature as a potential mediating factor between climate and conflict, we examine the effect of temperature during the growing and harvest seasons relative to during non-agricultural seasons. More precisely, we construct an indicator variable that takes the value of one for the months of April to September, which is considered the rainy season for the majority of Mexico and includes both the canicula and pre-canicula period.<sup>15</sup> The harvest season indicator variable, on the other hand, takes on a value of one during the months of October to December.

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<sup>15</sup>Canicula is a mid-summer drought period in Mexico. Both the growing and harvest season were specified following Skoufias (2012), who examines the effect of weather shocks on household welfare in Mexico.

We perform two different analyses. In the first one, we simply augment our main regression equation with an interaction between temperature and the indicator variable for the growing season. Our expectation is that this interaction will be positive if agricultural income is a mediating factor and if agricultural incomes (e.g. wages) respond rapidly to changes in temperature. Given that these income shocks might occur with some lag, with hot temperatures during the growing season only showing up as negative incomes shocks after crops have been harvested a few months later, our second approach studies how violence in the harvest season reacts to temperature shocks during the growing season.

Results are shown in Table 6. We find that temperature shocks during the growing season appear to *reduce* DTO killings somewhat, the opposite of what the agricultural income story would suggest, with the coefficient on the interaction not significant at conventional levels. For the test on whether growing season shocks affect harvest season violence, point estimates for both DTO killings and homicides are positive, but standard errors are too large to be able to rule out either zero effect or large positive or negative effects. Finally, we also include interaction terms with the percentage of households living in rural areas and the percentage of workers in the agricultural sector, and find similar results. Taken as a whole, these results provide little evidence that agricultural income is the critical mediating factor.

## 7 The role of non-economic factors in violence

Results from section 6 suggest that economic factors have only limited power to explain the observed effect between temperature and both intergroup and interpersonal violence in Mexico. We find that changes in temperature do not affect other economically motivated non-violent crimes, that other measures of economic conditions such as municipality-level income do not predict the temperature response, that random variation in governmental income assistance have only a modest dampening effect, and that growing season temperature shocks are not differentially harmful. None of these results is independently definitive, but together they suggest that economic factors are unlikely to be the driving force in explaining the large response of violence to temperature in this setting.

Could psychological factors instead explain the link between temperature and violence? Because inducing experimental variation in these factors is both impossible and likely highly undesirable, our approach to understanding their potential role is again indirect. In particular, our basic approach is a “pattern-matching” exercise, where we study whether the

response pattern of group violence to temperature matches the response pattern of another type of violence that is almost certainly lined to psychological factors – *intrapersonal* violence, i.e. suicide.

Suicide has long been understood to have a substantial psychological component. For instance, the medical literature tells us that psychiatric disorders are reported present in at least 90% of suicides (Mann et al., 2005), propensity toward suicidal behavior is strongly associated with genetic inheritance (Brent and Melhem, 2008), and randomized controlled trials suggest that suicide risk can be substantially shaped both by medications and by psychotherapy (Mann et al., 2005). Researchers have also long recognized the role that changes in temperature might play in shaping suicide risk, although the literature is currently inconclusive as to whether stark seasonal patterns in suicide (which characteristically peak during warm spring and summer months) are due to temperature *per se* or to other factors that also vary seasonally (see Appendix A.2 for a review of this literature).

Using an identical econometric strategy to that used for DTO killings and homicides above, we begin by showing that suicides in Mexico also respond strongly to deviations from average temperature. The non-parametric relationship between suicide and temperature is shown in Figure 5, and corresponding regression results are given in the first column of Table 8. As with DTO killings and homicides, the temperature-suicide relationship appears strongly linear, with an estimated standardized effect of a 7% increase in suicide per  $\sigma$  increase in temperature (Table 8).<sup>16</sup> This estimate falls between the estimated effects for DTO killings and homicides. As with these latter outcomes, the suicide response also appears fairly homogenous across states, with positive estimates in all but 2 states (see Figure A.2-C).

As with DTO killings and homicide, we then explore whether the temperature-suicide relationship is mediated by economic factors. This is, in essence, a further gut check on whether suicide is a fair “benchmark” for an outcome that we presume is mainly non-economic in nature. Results from including interactions with income, inequality, Progresa transfers, and growing season temperature are shown in the remaining columns of Table 8. Most coefficients on interactions are small and statistically insignificant, and the two interactions with statistical significance have signs that go in the opposite direction than what the typical income story would suggest: higher average incomes appear to slightly worsen the impact of hot temperatures, and hotter-than-average growing seasons appear to

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<sup>16</sup>Burke et al. (2018) provide further evidence of a positive causal effect of abnormally high temperatures on suicides rates in Mexico and the U.S.

reduce the impact of temperature.

As a final “pattern matching” exercise, we study the temporal pattern of how intergroup, interpersonal, and intrapersonal violence respond to temperature, using the leads/lags approach described in equation 4. As discussed above, studying the temporal pattern of responses can help shed additional light on mechanism, since income effects might be expected to show up with some lag in monthly data but physiological effects should show up immediately. Studying lags also allows us to understand whether contemporaneous effects are simply “displacement”, causing violence to occur earlier than it would have otherwise, but not changing the overall level of violence. Studying leads offers a simple placebo test, as future temperature should not affect current violence.

Results from estimating equation 4 on all three outcomes are shown in Figure 6, with point estimates and confidence intervals for contemporaneous effects, 6 lags, and 6 leads plotted for each outcome (for instance, a value of “-1” on the x-axis corresponds to the effect of temperature in month  $t - 1$  on violence in month  $t$ ). Although estimates are again more imprecise for DTO killings due to the smaller sample size, a number of common patterns are apparent. First, statistically significant effects occur only in contemporaneous periods for all three outcomes. That is, the most robust predictor of violence in a given month is temperature in that month, suggesting that the primary effects of temperature are immediate. We interpret this as additional evidence in favor of physiological mechanisms, since these would be expected to respond immediately to temperature change.

We also find evidence of some displacement, with lagged coefficients for both homicide and suicides negative and (for suicides) significant. In absolute value, these coefficients are about 1/3rd the size of the contemporaneous effects, suggesting that roughly one-third of the temperature-induced increase in homicides and suicides were events that were likely to have occurred anyway. Interestingly, we do not see a similar pattern for DTO killings, although generally larger standard errors on the DTO estimates limit our ability to say anything very precise. Finally, results on the leads (our placebo test) are largely reassuring, with most point estimates of the 6 leads near zero and none statistically significant.

We thus have two imperfect but consistent pieces of evidence that non-economic factors could explain some of the temperature-violence relationship. The first is that a known psychologically-dependent outcome, suicide, responds strikingly similarly to changes in temperature. We view the extent of this similarity as unlikely if suicide did not share some underlying commonalities with these other forms of violence. The second is that the effect

of temperature on all types of violence that we measure is immediate – i.e. that it occurs in the same month as the temperature shock – which is inconsistent with the most obvious income-related stories in which temperature reduces agricultural output, given that the period in which crops are sensitive to temperature is temporally disjoint from the period in which harvest income is realized. Again, each of these pieces of evidence on their own might not be convincing, but together they suggest a substantial role for non-economic factors in explaining how both intergroup and interpersonal violence in Mexico respond to changes in temperature.

## 8 Conclusion

Using municipality by month variation in temperature, we find significant contemporaneous effects of temperature on DTO killings, homicides, and suicides in Mexico. Estimated effects are economically meaningful for each outcome, and imply that temperature can induce large additional increase in violence on top of already high baseline levels of both DTO killings and homicides. This is the first study to our knowledge to find such a similar relationship across a spectrum of violence outcomes in a single setting, and our estimated effects are surprisingly consistent with existing estimates in the literature from other settings.

Using a variety of approaches and data, we then study whether economic factors likely mediate this observed link between temperature and violence, or whether non-economic factors are more likely at play. A constellation of evidence, including the limited influence of a cash transfer program as well as comparison with economically-motivated non-violent DTO crimes, indicate that economic factors can at best only partially explain the observed relationship between temperature and violence. We present two pieces of evidence that suggest a role for non-economic factors in explaining the temperature-violence link for group- and interpersonal violence: the substantial similarity between how these outcomes respond to temperature and how suicide responds to temperature, and the immediacy of the response of these variables to changes in temperature.

We draw two tentative policy implications from our findings. The first is that, at least in this particular setting, economic interventions might not be an effective tool for shaping how violence responds to changes in climate. Second, our results are equally pessimistic on the role for adaptation in shaping this response, with neither higher average income levels nor specific interventions that alter how individuals experience climate (i.e. air conditioning)

appearing to affect how violence responds to temperature. Reducing future temperature increases through emissions mitigation, rather than trying to induce adaptation through policy intervention (or hoping that it will occur on its own), thus unfortunately appears the most fruitful strategy in this setting for limiting the violent consequences of climate change.

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Figure 1

Spectrum of Violence

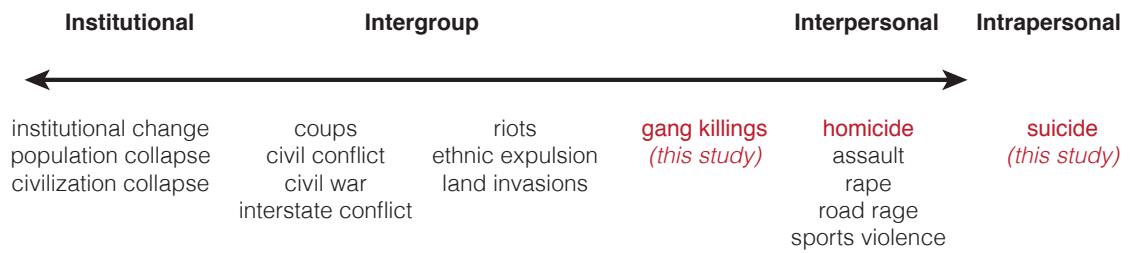
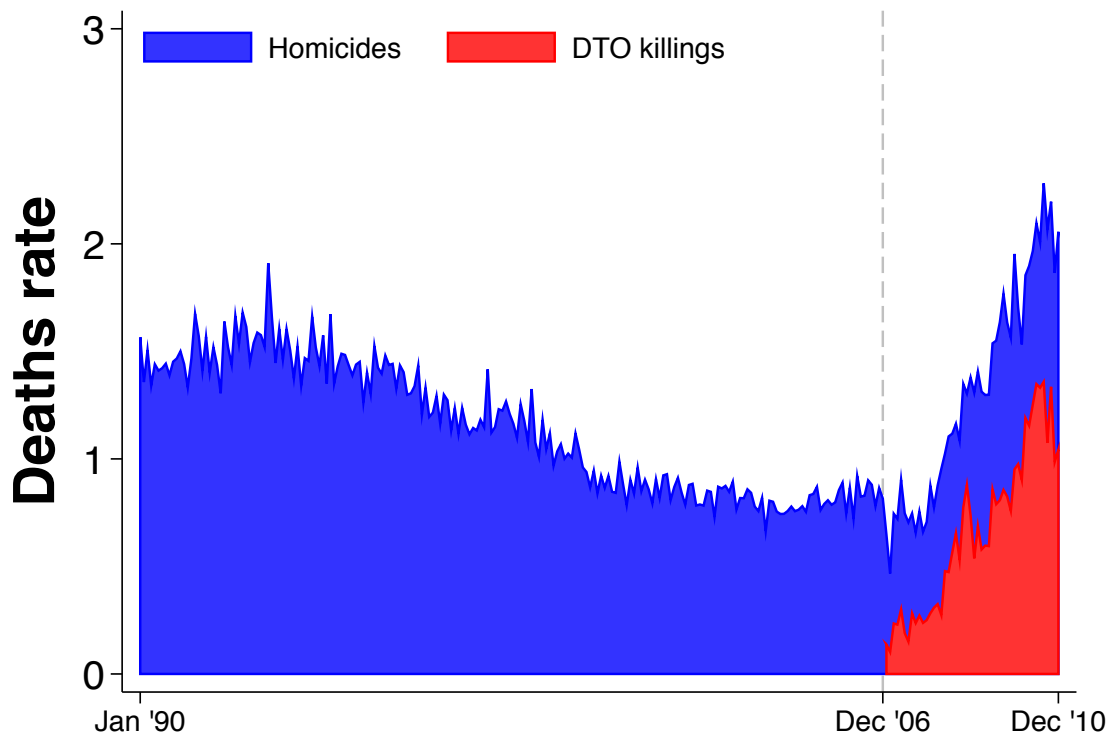
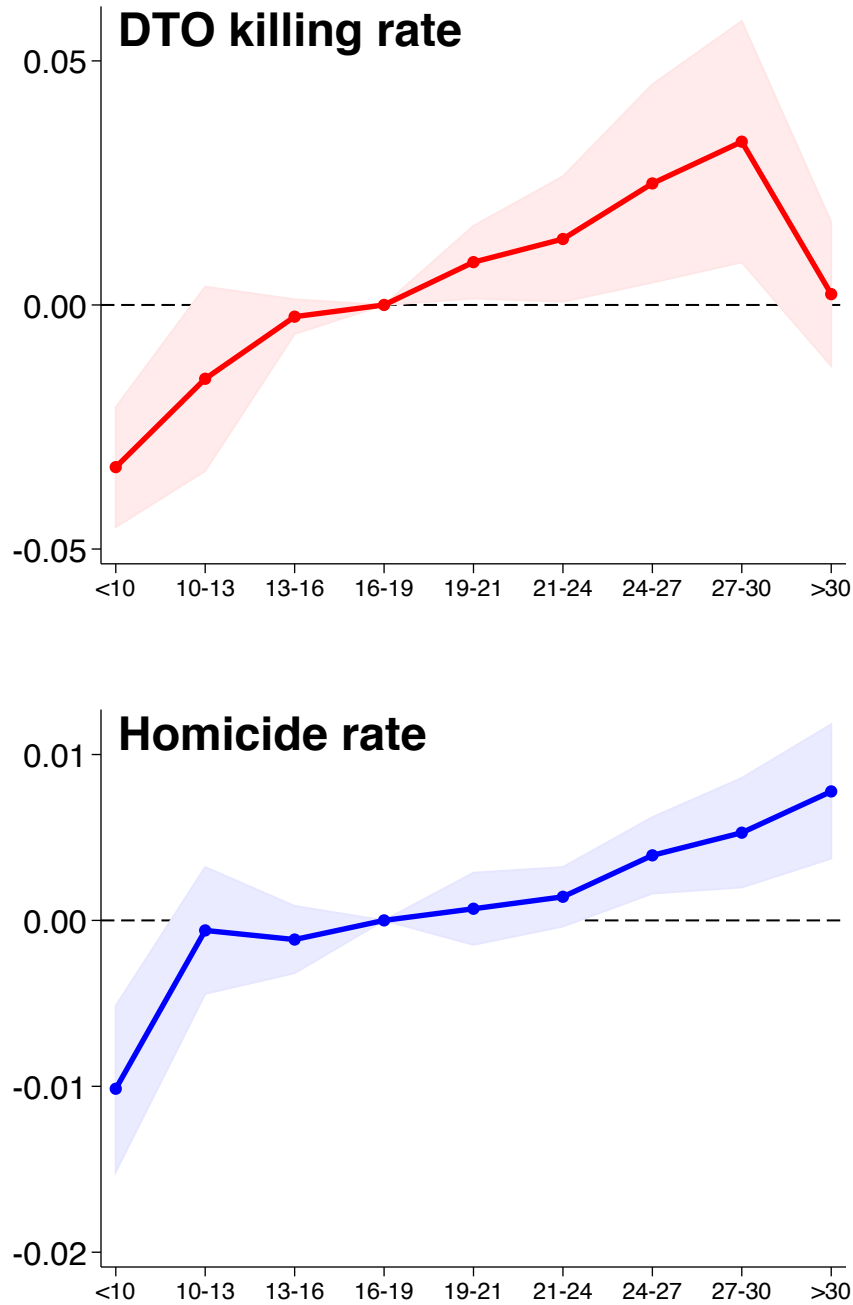


Figure 2: Time series in violence



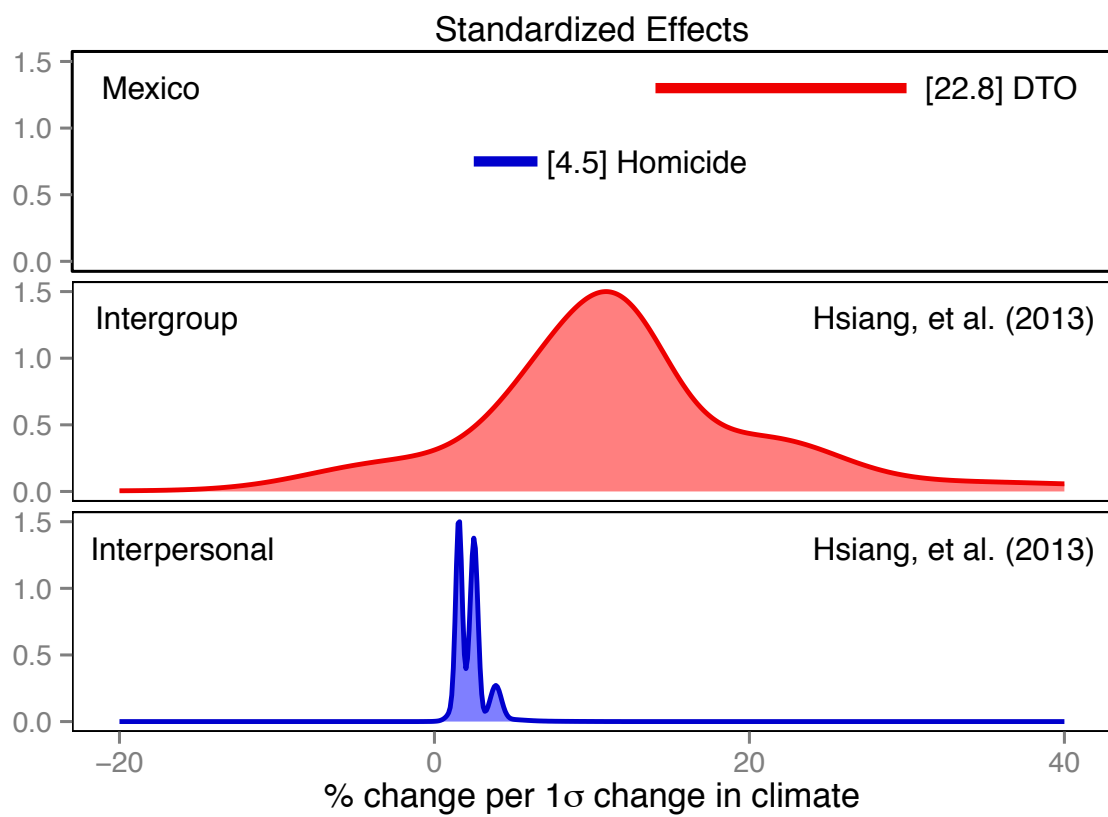
Notes: Time averages (weighted by population) for our main outcome variables in all municipalities in Mexico. The dash vertical black line denotes the beginning of the Mexican Drug War.

Figure 3: Temperature and violence in Mexico



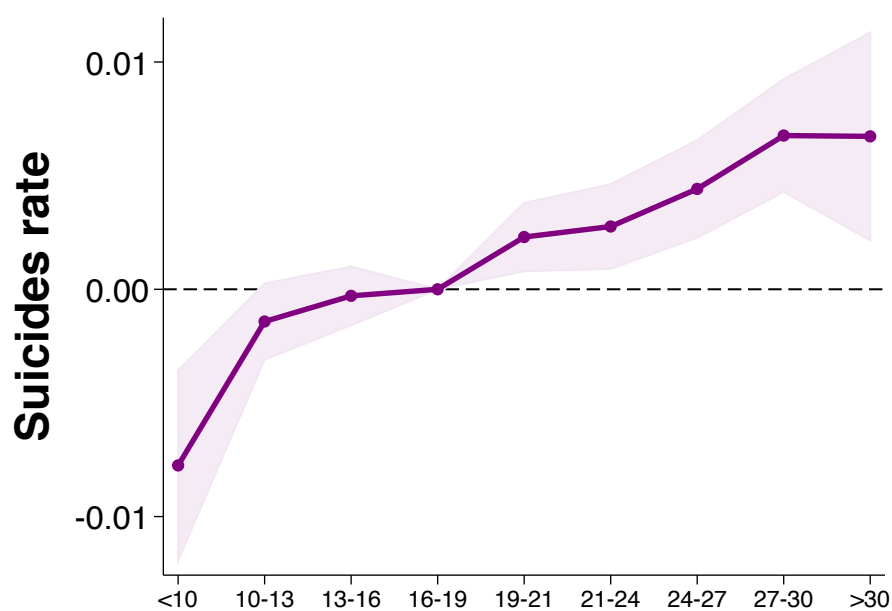
*Notes:* These figures present non-parametric estimates of equation (3). Temperature response functions for DTO killings (upper panel) and homicides (lower panel) using temperature bins of width 3°C. The  $x$ -axis is interpreted as the average temperature in a given municipality-month, and the  $y$ -axis is interpreted as deviation from that municipality-month average in the corresponding measure of violence.

Figure 4: Meta-analysis



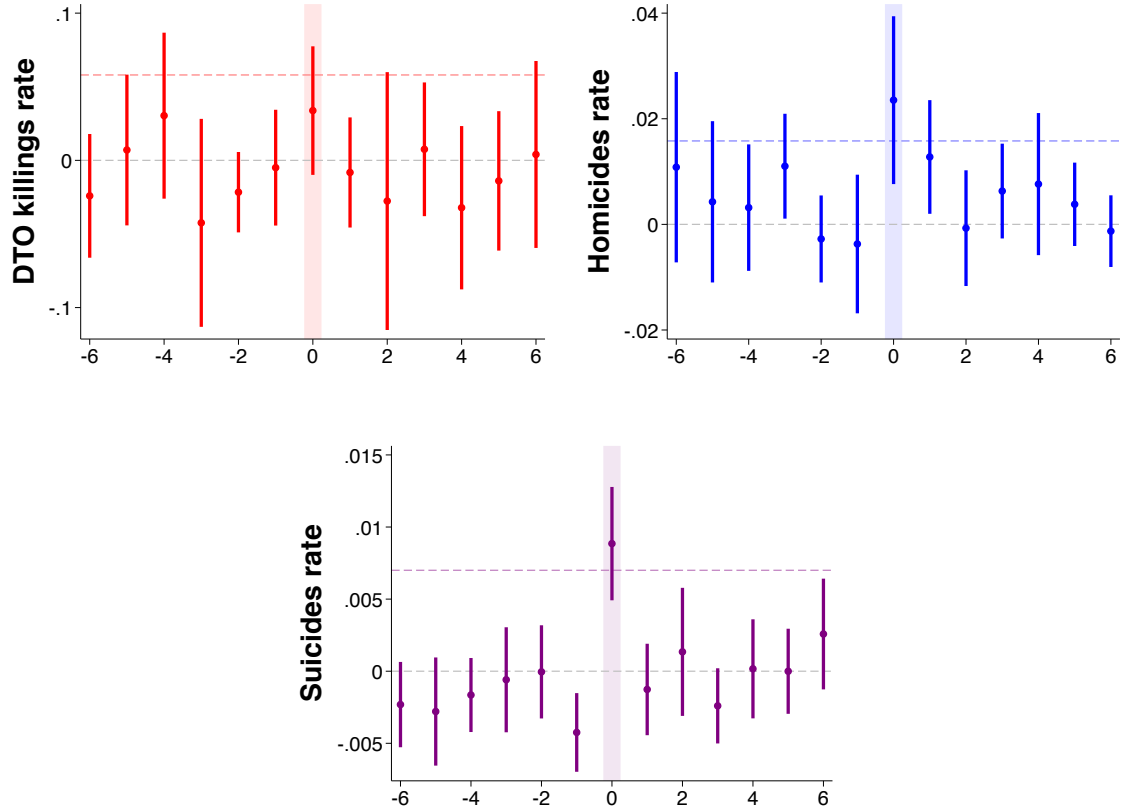
Notes: **Top panel** presents estimated standardized effects and confidence intervals from this study. **Bottom panels** show the distribution of standardized effects of climate on interpersonal (e.g. rapes) and intergroup (e.g. civil conflict) outcomes from Hsiang et al. (2013).

Figure 5: Temperature and suicides



*Notes:* This figure presents non-parametric estimates of equation (3). These temperature response functions use bins of width 3°C. The  $x$ -axis is interpreted as the average temperature in a given municipality-month, and the  $y$ -axis is interpreted as deviation from that municipality-month average in suicides per 100,000 inhabitants.

Figure 6: Temporal distribution of estimates



Notes: This figure shows regression estimates  $\beta_{t+k}$  of the following regression equation:

$$y_{smt} = \xi_m + \lambda_t + \zeta_s + \sum_{k=-6}^6 \beta_{t+k} \text{Temp}_{sm,t+k} + \sum_{k=-6}^6 \delta_{t+k} \text{Precip}_{sm,t+k} + \varepsilon_{smt}$$

where  $y_{smt}$  is DTO killings, homicides, or suicides per 100,000 people,  $\xi_m$ ,  $\lambda_t$ , and  $\zeta_s$  are month, year, and municipality fixed effects respectively,  $\text{Temp}_{smt}$  and  $\text{Precip}_{smt}$  are temperature (in degrees celsius) and precipitation (in millimeters) respectively, and  $\varepsilon_{smt}$  is an error term.

**Table 1: Descriptive statistics**

<i>Period:</i>	<i>January 1990 – December 2006</i>		<i>January 2007 – December 2010</i>	
	Mean	St. Dev.	Mean	St. Dev.
DTO killings per 100,000 inhabitants	–	–	0.59	7.88
Homicides per 100,000 inhabitants	0.98	5.23	0.83	4.14
Suicides per 100,000 inhabitants	0.21	1.93	0.26	2.21
Population	39,057	116,901	44,584	130,760
Temperature (°C)	20.10	5.00	20.05	5.09
Precipitation (millimeters)	92.87	111.83	80.70	107.09
Municipalities	2,456		2,456	
Observations	493,908		117,458	

*Notes:* Each observation corresponds to a municipality-month. Population is estimated using linear interpolations within municipalities with the 1990, 2000, and 2010 Census as reference numbers. Temperature and precipitation are weighted by population. The summary statistic **St. Dev within** is the standard deviation of the corresponding variable after removing municipality fixed effects.

**Table 2: Temperature and violence in Mexico**

<i>Dependent variable:</i>	<i>DTO killings</i>			<i>Homicides</i>		
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Temperature</b>	0.058** (0.022) [28.4]	0.066** (0.030) [33.6]	0.053*** (0.019) [26.9]	0.016*** (0.004) [4.7]	0.023** (0.011) [7.0]	0.014*** (0.003) [4.3]
<b>Precipitation</b>	0.016 (0.041) [2.7]	-0.013 (0.027) [-2.2]	0.025 (0.035) [4.2]	-0.004 (0.007) [-0.4]	-0.001 (0.007) [-0.1]	-0.009* (0.005) [-0.9]
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Month F.E.	Yes	No	Yes	Yes	No	Yes
Month–state F.E.	No	No	Yes	No	No	Yes
State trends	No	Yes	No	No	Yes	No
Observations	117,458	117,458	117,458	493,908	493,908	493,908

*Notes.* Each observation corresponds to a municipality-month. Estimates of equation (3) using data for all municipalities in Mexico in different periods (1990–2006 in columns 1–3, 2007–2010 in columns 2–6). **State trends** is a complete set of year indicators interacted with state indicators. Standard errors clustered at the state level in parenthesis. Standardized effects in brackets. All regressions are weighted by population. Levels of significance are reported as \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

**Table 3: Temperature and economically motivated crimes**

<i>Dependent variable:</i>	<i>DTO killings</i>	<i>Homicides</i>	<i>Car thefts</i>	<i>Extortions</i>	<i>Kidnappings</i>
	(1)	(2)	(3)	(4)	(5)
<b>Temperature</b>	0.050** (0.024) [22.8]	0.050** (0.023) [13.7]	0.067 (0.092) [1.7]	-0.005 (0.004) [-4.5]	-0.001 (0.001) [-3.1]
<b>Precipitation</b>	0.080 (0.447) [0.8]	-0.285 (0.411) [-1.7]	-0.363 (2.430) [-0.2]	0.220 (0.255) [3.9]	0.060 (0.036) [6.2]
Mean of dep. variable (Within st. dev.)	0.737 (0.962)	1.217 (0.827)	13.414 (5.600)	0.407 (0.360)	0.070 (0.088)
Municipality, year & month F.E.	Yes	Yes	Yes	Yes	Yes
Observations	1,536	1,535	1,535	1,535	1,534
R <sup>2</sup>	0.649	0.714	0.886	0.603	0.392

*Notes.* Each observation corresponds to a state-month. Estimates using data for all states in Mexico in the period 2007 – 2010. All dependent variables are rates per 100,000 inhabitants. Source is *Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública* (SESNSP). Standard errors clustered at the state level in parenthesis. Standardized effects in brackets. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.



**Table 4: Interaction with economic variables**

<i>Dependent variable:</i>	<i>DTO killings</i>				<i>Homicides</i>			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<b>Temperature</b>	0.063** (0.024)	0.059** (0.023)	0.082** (0.038)	0.060** (0.023)	0.014*** (0.004)	0.016*** (0.004)	0.021*** (0.005)	0.016*** (0.004)
× <b>Income (1990)</b>	-0.008 (0.011)				0.003 (0.002)			
× <b>Gini (1990)</b>		-0.007 (0.007)				0.001 (0.003)		
× <b>Houses with air conditioning (2010)</b>			-0.007 (0.006)				-0.002* (0.001)	
× <b>Average temperature (1990–2010)</b>				-0.006 (0.008)				0.000 (0.002)
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	114,384	113,616	28,752	117,458	486,132	482,868	121,056	493,908

*Notes.* Each observation corresponds to a municipality-month. Estimates use data for the period 2007-2010 in columns 1-4 and for the period 1990-2006 in columns 5-10. Income and gini are own calculations using the 1990 Census. Houses with air-conditioning is data from *Encuesta Nacional de Ingresos y Gastos de los Hogares* in Mexico and it is available for a subsample of 600 municipalities. Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

**Table 5: Progresa transfers**

<i>Dependent variable:</i>	<i>DTO killings</i>			<i>Homicides</i>		
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Temperature</b>	0.039** (0.018)	0.039** (0.018)	0.039** (0.018)	0.012*** (0.003)	0.012*** (0.003)	0.012*** (0.003)
<b>Progresa transfers</b>		-0.009 (0.013)	-0.009 (0.013)		0.003 (0.012)	0.004 (0.012)
<b>Progresa transfers × Temperature</b>			0.001 (0.003)			-0.001 (0.002)
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Month F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	88,092	88,092	88,092	262,992	262,992	262,992

*Notes.* Each observation corresponds to a municipality-month. Estimates use data for the period 2007-2010 in columns 1-3 and for the period 1998-2006 in columns 4-6. Progresa transfers is the total amount of transfers to a municipality divided by total population. Estimates restricted to the period 1998–2009, in which the program Progresa/Oportunidades was being implemented. Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

**Table 6: Interaction with agricultural variables**

<i>Dependent variable</i>	<i>DTO killings</i>				<i>Homicides</i>			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<b>Temperature</b>	0.058** (0.022)	0.068*** (0.020)	0.060*** (0.016)	0.058*** (0.017)	0.016*** (0.004)	0.013** (0.005)	0.015*** (0.005)	0.015*** (0.005)
× <b>Growing season indicator</b>		-0.022 (0.043)				0.005 (0.006)		
× <b>Households in rural areas (1990)</b>			0.002 (0.011)				-0.000 (0.002)	
× <b>Workers in agricultural sector (1990)</b>				0.000 (0.009)				-0.000 (0.002)
Municipality F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	117,458	117,458	115,008	115,008	493,908	493,908	488,784	488,784

*Notes.* Each observation corresponds to a municipality-month. Estimates use data for the period 2007-2010 in columns 1-5 and for the period 1990-2006 in columns 5-8. Growing Season as an indicator for the months of April to September; this is considered the wet season for the majority of Mexico and includes both the canicula and pre-canicula period. Canicula is a mid-summer drought period in Mexico. The harvest season is during the months of October through December. We specified these months following Skoufias (2012) who look at the effect of weather shocks on household welfare in Mexico. All regressions control for **precipitation** and are weighted by population. Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

**Table 7: Drug-trafficking organizations**

*Dependent variable is DTO killings per 100,000 inhabitants (years: 2007–2010)*

<i>DTO variable:</i>	None	Indicator some	Indicator Zetas	Number DTOs
	(benchmark)	DTO operating	operating	operating
	(1)	(2)	(3)	(4)
<b>Temperature</b>				
	0.058** (0.022)	0.046** (0.021)	0.048** (0.022)	0.024* (0.013)
$\times$ <i>DTO Variable</i>		0.013 (0.008)	0.018** (0.007)	0.014** (0.006)
<i>DTO variable</i>		-0.043 (0.148)	0.274 (0.165)	0.320 (0.205)
Municipality F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
Month F.E.	Yes	Yes	Yes	Yes
Observations	117,458	117,446	117,446	117,446

*Notes.* Each observation corresponds to a municipality-month. Estimates use data for the period 2007–2010. Presence of a drug-trafficking organization (DTO) at the municipality-year level comes from Coscia and Rios (2012). Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

**Table 8: Temperature and suicides in Mexico**

*Dependent variable is suicides rate per 100,000 inhabitants*

<i>Economic variable:</i>	None (benchmark)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			Income	Gini	Houses with air conditioning	Municipality average temperature	Progresa transfers	Growing season	Households in rural areas	Workers in agricultural sector
<b>Temperature</b>	0.007*** (0.001)		0.006*** (0.001)	0.007*** (0.001)	0.005*** (0.001)	0.007*** (0.001)	0.009*** (0.001)	0.009*** (0.002)	0.007*** (0.001)	0.006*** (0.001)
× <i>Economic variable</i>			0.001 (0.001)	0.000 (0.001)	0.001 (0.001)	0.001 (0.001)	-0.001 (0.002)	-0.004** (0.002)	-0.000 (0.001)	-0.001 (0.001)
<i>Economic variable</i>			-	-	-	-	-0.009* (0.005)	-0.004 (0.010)	-	-
Municipality F.E	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month F.E	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	493,908		486,132	482,868	121,056	493,908	262,992	493,908	488,784	488,784

*Notes.* Each observation corresponds to a municipality-month. Estimates use data for the period 1990-2006 except in column 6 in which we use data for the period 1998-2006. Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

## ONLINE APPENDIX

*Economic and Non-Economic Factors in Violence:  
Evidence from Organized Crime, Suicides and Climate in Mexico*

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## A Literature Review

### A.1 Consequences of violence

There is a large literature in economics and political science documenting the negative effects of crime, conflict, and war (from now on “conflict”) on different outcomes. For example, in relatively new papers researchers have documented the effect conflict has on health outcomes (Bundervoet et al. 2009, Baez 2011, Akresh 2012, Akbulut-Yuksel 2014b), human capital formation (Blattman and Annan 2010, Shemyakina 2011, Chamarbagwala and Moran 2011, León 2012, Verwimp and Van Bavel 2014, Akbulut-Yuksel 2014a), labor outcomes (Kondylis 2010, Fernandez et al. 2011, Bozzoli et al. 2012), consumption (Serneels and Verpoorten 2013, Velasquez 2014), agricultural investment (Singh, 2012), firm exit (Camacho and Rodriguez, 2012), family formation (Akbulut-Yuksel et al., 2013), wages and prices (Rozo, 2014), and the development of institutions (Voors, 2014). Reviewing this large literature is beyond the scope of this paper, but it is clear that conflict has increasingly negative and pervasive effects in societies.<sup>17</sup>

Researchers have also started to document the consequences of the dramatic increase in violence after 2007 in Mexico. For example, Rios (2014) shows that cities on the U.S.–Mexico border have received relatively more Mexican immigrants in recent years, despite the fact that Mexican immigration to the U.S. reached its lowest point since 2000 across the country as a whole (Cave 2011, The Economist 2012). Other researchers have estimated the impact on labor markets. Robles et al. (2014) use an instrumental variables approach and finds that violence has had negative effects on labor participation and unemployment, and caused a decrease in local economic activity.<sup>18</sup> In the same line of research, Velasquez (2014) uses a differences-in-differences approach at the individual level and finds that increased violence (i) decreases labor market participation and the number of hours worked by self-employed women, (ii) decreases hourly and total earnings of self-employed males, and (iii) decreases per capita expenditure. In addition, Brown (2014) findings suggest that the escalation of violence decreased average birth weight by 70 grams ( $\sim 40$  percent), and by  $\sim 120$  for mothers with low socioeconomic status.<sup>19</sup> In a related study, Leiner et al. (2012) results suggest that exposure to violence causes mental health problems (e.g. depression, anxiety, attention, aggressive behavior).

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<sup>17</sup>See Blattman and Miguel (2010) for a review of the literature before 2010, and Miguel and Roland (2011) for long-run consequences of violent events.

<sup>18</sup>The same authors also find evidence of spillovers from homicides to other criminal activities such as extortions, kidnappings, and car thefts, something also noted by Guerrero (2010) and Brown (2014).

<sup>19</sup>For comparison, this effect is larger than estimates of the positive impact on birth weight of federal nutrition programs such as the Supplemental Nutrition Program for Women, Infants, and Children, and the Food Stamp Program in the United States.

## A.2 Seasonality in suicides

For empirical studies analyzing the relationship between temperature and suicides see Rohden (1933), Mills (1934), Pokorny et al. (1963), Grove and Lynge (1979), Dixon and Shulman (1983), Chiu (1988), Marion et al. (1990), Souetre et al. (1990), Linkowski et al. (1992), Barker et al. (1994), Salib and Gray (1997), Jessen et al. (1998), Preti and Miotto (1998), Yan (2000), Leung et al. (2002), Deisenhammer et al. (2003), Lee et al. (2006), Ajdacic-Gross et al. (2007), Preti et al. (2007), Hajat et al. (2007), Qi et al. (2009), Toro et al. (2009), Ruuhela et al. (2009), Tsai (2010), Likhvar and Honda (2011), Kim et al. (2011), Yang et al. (2011), Inoue et al. (2012), Helama et al. (2013), Holopainen et al. (2013). See Ajdacic-Gross et al. (2010) and Christodoulou et al. (2012) for a review of the literature on the seasonality of suicides, Deisenhammer (2003) for a review of the literature on weather and suicides until 2003. See Burke et al. (2018) for a summary of the more recent studies.

## B Additional Data

In this section we describe our additional data sources and the construction of variables associated with it. We proceed describing variables in the same order that they appear on the main text.

### B.1 Drug Trafficking Organizations

We use a number of variables related to the presence of a drug trafficking organization (DTO) in a state. In particular, we use two sets of variables: (1) the number of DTOs operating in a state  $s$  in year  $t$ , and (2) the shares of the state where the DTOs “Sinaloa” and “Zetas” operate. We define a share of some DTO as the total number of municipalities where that DTO operates over total number of municipalities in that state. We chose these two DTOs because anecdotal evidence (and some quantitative evidence we show later on) shows that the Zetas have been trying to take control over the territory controlled by Sinaloa, and hence many DTO killings seem to be associated with this rivalry.

The data we use to construct these variables comes from Coscia and Rios (2012). These authors use newspapers and blogs, aggregated through Google News, as sources of information to estimate where DTOs operate. In particular, they generate a panel dataset of all municipalities in Mexico, observed *yearly* between 1990 and 2010, with ten indicator variables (one for each DTO). These indicator variables take the value of one if the corresponding DTO is operating in that municipality.

There are two main differences between this DTO dataset and ours. First, we work with states in our analysis, while DTO operations are recorded at the municipality level. Second, our time interval is a month, while DTO operations are recorded on a yearly basis. To facilitate exposition, let  $k = 1, \dots, 10$  represent a certain DTO. To merge DTO operations with our dataset we collapse the yearly data at the state level and create (i) a series of



indicator variables  $DTO_{kst}$  that take the value of one if a DTO  $k$  is operating in state  $s$  and year  $t$ , and (ii) the corresponding state shares previously described. When doing this we assign yearly information to all months in that year.

Then, we construct our three main variables in the following way. The variable  $DTOs$  is simply the sum of DTOs operating in state  $s$  and year  $t$ , i.e.  $DTO_{st} = \sum_{k=1}^{10} D_{kst}$ . The shares are defined as previously mentioned. In order to show some evidence for the rivalry between Sinaloa and the Zetas, we collapsed our dataset at the state-year level and ran the following regression:

$$y_{st} = \alpha + \lambda_t + \zeta_s + \sum_{k=1}^{10} \beta_k DTO_{kst} + \varepsilon_{st}$$

where  $y_{st}$  is DTO killings for each 100,000 inhabitants,  $\alpha$  is a constant term,  $\lambda_t$  is a year fixed effect,  $\zeta_s$  is a state fixed effect,  $DTO_{kst}$  are ten indicator variables, and  $\varepsilon_{st}$  is an error term clustered at the state level. Then, a DTO  $k$  is classified as violent if  $\beta_k > 0$  and is statistically significant. Figure A.3 presents estimates of this regression equation. Note that the Zetas are operating in every state-month in our sample, so these regression estimates effectively show how DTO killings respond to the presence of DTO pairs of Zetas and another organization. We can see from this figure that the only DTO pair that is statistically associated with DTO killings is the one Zetas-Sinaloa. Sinaloa operates in 46 percent of state-years in our sample period. Descriptive statistics for all these variables are presented in Table A.2.

## B.2 Criminal activities

In Table 6 we use a different data source to measure (1) homicides, and we add three variables measuring criminal activities that have a clear economic objective: (2) kidnappings, (3) extortions, and (4) car thefts. This data was collected by the *Secretariado Ejecutivo del Sistema Nacional de Seguridad Pública* (SESNSP) at the Mexican Secretariat of the Interior (*Secretaría de Gobernación*).

To incorporate this information into our dataset we downloaded it from the website of the Mexican Secretariat of the Interior. The raw data is transformed into rates per 100,000 inhabitants in the state using population census data. The only exception is car thefts. When using this variable we add up the raw variables *robo de vehículo con violencia* (violent car theft), and *robo de vehículo sin violencia* (non-violent car theft) to create a variable we call “car thefts”. There are, on average, 39 homicides, 2.4 kidnappings, 13 extortions, and 515 car thefts in a state-month in the period between January of 2007 and December of 2010. Table A.2 presents descriptive statistics for these variables in rates, showing the overall standard deviation, and the deviation after removing state, year, and month fixed effects.

Although these variables are available at the state-month level for the period 1997–2014, we only use them for the period 2007–2010 to be consistent with our empirical analysis. Finally, we refer the reader to Merino (2011) for a comparison between this alternative

homicide variable and the two variables we use in our main empirical analysis (i.e. DTO killings and homicides from Mexico’s Bureau of Statistics).

### B.3 Economic variables

In Table 5 we use a series of economic variables. *Log GDP per capita* is measured in 1999 at 1993 prices and the source is Mexico’s Bureau of Statistics (INEGI). *Houses with air-Conditioning* is the saturation of residential air-conditioning, from the National Household Income and Expenditure Survey of 2010. This measure is based on an indicator variable for whether a household has an air-conditioning unit, which falls under the category of durable goods. This measure was then aggregated to the state level using ENIGH sampling weights. *Gini* is an income inequality index constructed by Jensen and Rosas (2007) using the 1990 and 2000 Mexican national census. The authors calculate the Gini indices using methods proposed by Abounoori and McCloughan (2003) and Milanovic (1994). Finally, *Unemployment* is monthly unemployment data for each state from the National Survey of Employment and Occupation, and is available since March of 2005 until the end of our period of study.

### B.4 Progresa transfers

In Table 3 we use variation in income generated by the program OPORTUNIDADES in Mexico. This social program started in 1997 with the name of PROGRESA (*Programa de Educación y Salud*, Education and Health Program), and it consisted of conditional cash transfers that targeted poor families in marginal rural areas between 1997 and 2002. A main feature of this program is that it included an evaluation component from its inception. From 2002 the program changed its name and scope and began to incorporate urban areas as well. The budget for this program was approximately 133 million USD in 1997 ( $\sim 0.03\%$  of GDP), and it has expanded to almost 5 billion USD in 2010 ( $\sim 0.5\%$  of GDP).

We downloaded bimonthly monetary transfers to each state from the program’s official website. This information is available for the OPORTUNIDADES program, i.e. from 2002 onwards. In our empirical analysis we use the logarithm of one plus the total amount of bimonthly transfer to a state. Less than 2% of observations correspond to no monetary transfers (i.e. transfer equals zero) in the period we analyze. We take a bimonthly transfer, e.g. 100 USD in January-February, and we split it equally between both months, i.e. 50 USD in January and 50 USD in February. Descriptive statistics for this variable are presented in Table A.2.

### B.5 Wage and unemployment

In Panels A and B of Figure A.6 we plot the average bimonthly income and unemployment of agricultural and non-agricultural workers in Mexico. To construct this data we use the National Household Survey of Income and Expenditure (*Encuesta Nacional de Ingresos y*

*Gastos de los Hogares*), officially managed by the Mexico's National Bureau of Statistics since 1984. This is a nationally representative survey of rural and urban areas, and is done every two years since 1992. For these calculations we use the years 1989, 1992, 1994, 1996, 1998, 2000, 2002, and 2004.

The interviews for this survey are done between the months of July and October. One part of this questionnaire constructs, retrospectively, workers' income in the past 6 months. In addition, the occupation of the individual is always part of this questionnaire. Exploiting variation in the distribution of interviews, and classifying individuals in the agricultural and non-agricultural sectors, we were able to construct (i) average monthly income, and (ii) percentage of individuals without income, both from February to October. Finally, we construct two months bins from these numbers to estimate seasonality in income and unemployment for both sectors.

**Table A.1:** Operation of Mexican drug cartels

Cartel	Municipalities in 2010	Start Year	Entry	Exit	Years Operated
Sinaloa	176	1993	25.6	17.0	2.8
Golfo	244	1994	35.6	23.5	3.0
Juárez	74	1997	13.9	10.2	2.8
Tijuana	39	1997	10.1	8.2	2.7
Zetas	405	2003	42.2	22.0	2.8
Beltrán-Leyva	157	2004	18.7	10.8	2.1
Fam	227	2005	18.8	7.4	2.1
Barbie	66	2006	5.8	2.5	1.6
Mana	32	2006	3.8	2.2	2.2
Sinaloa*	53	2008	5.2	2.5	2.0
Beltrán-Leyva*	57	2008	5.0	2.2	1.8
Other	24	2008	2.2	1.0	1.4

*Source:* Table 1 in Coscia and Rios (2012). Entry is the average number of municipalities cartel  $k$  enters in a year. Exit is the average number of municipalities cartel  $k$  exits in a year. Years operated is the average number of years cartel  $k$  operates in a municipality. \*Factionalized cartel.

**Table A.2:** Descriptive statistics for additional variables

	<i>Mean</i>	<i>St. Dev.</i>	<i>St. Dev within</i>	<i>Min</i>	<i>Max</i>
<i>Criminal activities</i>					
Homicides	1.22	1.54	0.83	0	11.92
Kidnappings	0.07	0.11	0.09	0	0.90
Extortions	0.41	0.57	0.36	0	5.91
Car thefts	13.41	16.56	5.60	0	112.00
<i>Drug trafficking organizations</i>					
DTOs	6.30	2.47	0.92	1	10
Sinaloa	0.03	0.05	0.03	0	0.27
Zetas	0.21	0.21	0.08	0	0.94
<i>Other</i>					
Log Progresas transfers	17.24	3.75	2.88	0	20.16

*Notes:* Descriptive statistics for all 32 Mexican states at the month level during the period between January of 2007 and December of 2010.

**Table A.3:** Including temperature in the previous month

	<i>DTO killings</i>		<i>Homicides</i>		<i>Suicides</i>	
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Temperature<sub>t</sub> (<math>\alpha</math>)</b>	0.035** (0.016)	0.063 (0.046)	0.019*** (0.003)	0.013*** (0.004)	0.011*** (0.002)	0.007*** (0.002)
<b>Temperature<sub>t-1</sub> (<math>\beta</math>)</b>	0.020 (0.036)		-0.007 (0.004)		-0.006*** (0.001)	
<b>Temperature<sub>t+1</sub> (<math>\beta</math>)</b>		-0.017 (0.032)		0.003 (0.004)		0.000 (0.002)
$\alpha + \beta$	0.055* (0.032)	0.046** (0.019)	0.012*** (0.004)	0.015*** (0.003)	0.006*** (0.002)	0.007*** (0.001)
State, year & month F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,536	1,504	6,496	6,528	6,496	6,528
R <sup>2</sup>	0.649	0.644	0.697	0.697	0.472	0.470

*Notes:* Estimates for all 32 states in Mexico. All regressions include state, year, and month fixed effects, and precipitation as control variable. Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

**Table A.4:** Drug trafficking organizations

	<i>Dependent variable is DTO killings</i>				
	(1)	(2)	(3)	(4)	(5)
<b>Temperature</b>	0.050** (0.024)	0.049** (0.024)	0.048** (0.024)	0.049* (0.025)	0.046* (0.025)
× <b>DTOs</b>		0.005 (0.004)			
× <b>Sinaloa</b>			0.279 (0.317)		0.242 (0.306)
× <b>Zetas</b>				0.109 (0.086)	0.116 (0.090)
× <b>Sinaloa × Zetas</b>					1.371 (2.682)
<b>DTOs</b>		0.071 (0.082)			
<b>Sinaloa</b>			6.627** (2.890)		6.909** (2.794)
<b>Zetas</b>				-0.021 (0.983)	0.203 (1.011)
<b>Sinaloa × Zetas</b>					-21.777 (27.452)
Mean of dep. variable (Within st. dev.)	0.737 (0.962)				
State, year & month F.E.	Yes	Yes	Yes	Yes	Yes
R <sup>2</sup>	0.649	0.651	0.665	0.649	0.666

*Notes.* See Appendix for data on drug-trafficking organizations. **DTOs** is the number of cartels that are operating in State  $s$  and year  $t$ . **Sinaloa** and **Zetas** are the *shares* of the state in which these DTOs operate. *Share* is defined as total number of municipalities where they operate over total number of municipalities in that state. All regressions control for precipitation. Standard errors clustered at the state level in parenthesis. Levels of significance are reported as \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ , + $p < 0.11$ .

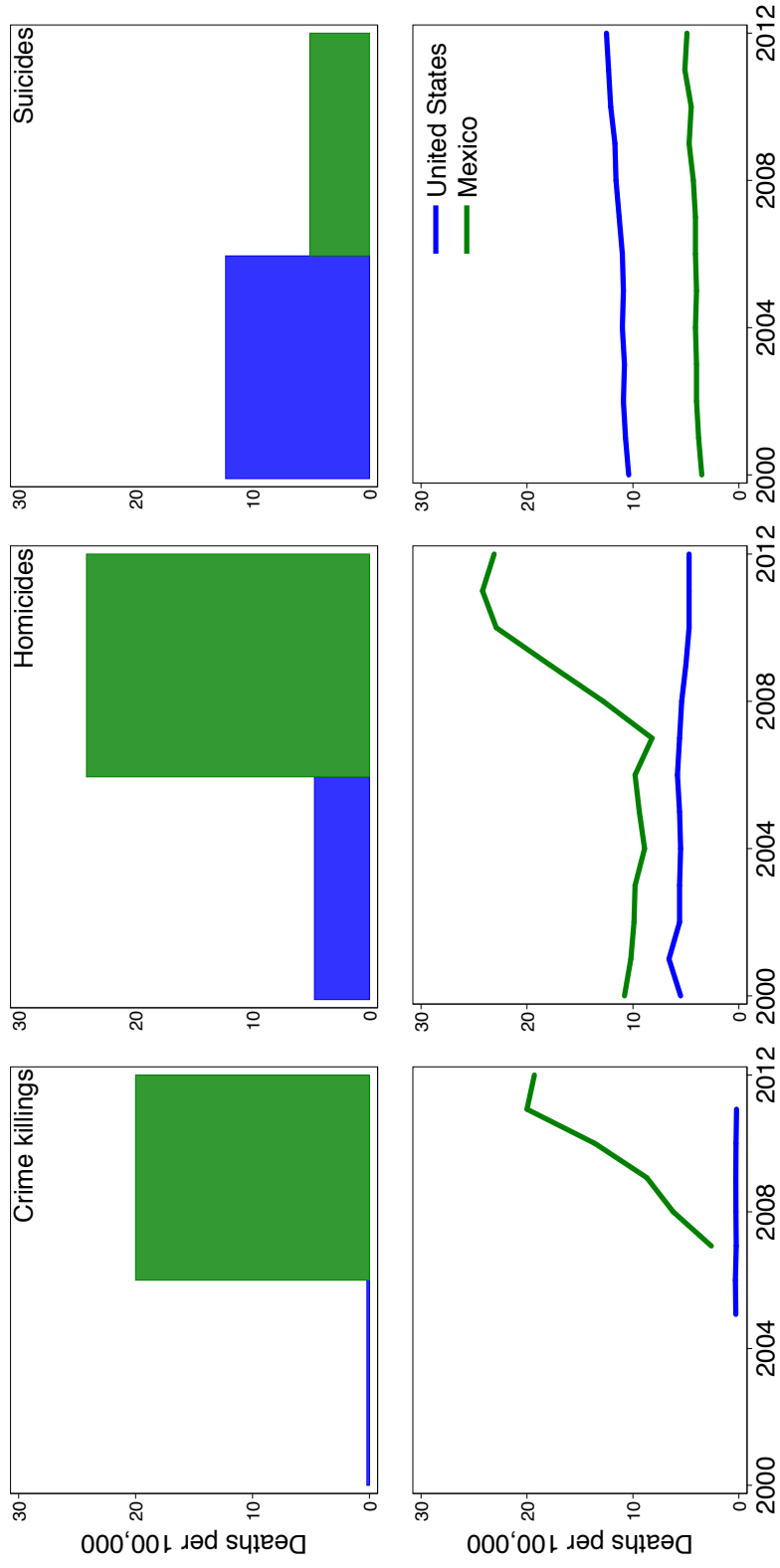
**Table A.5:** Temperature and suicides in Mexico

<i>Dependent variable:</i>	<i>Suicides</i>		
	(1)	(2)	(3)
<b>Temperature</b>	0.007*** (0.001) [7.4]	0.007*** (0.001) [7.2]	0.009** (0.003) [8.7]
<b>Precipitation</b>	-0.053 (0.039) [-1.3]	-0.034 (0.038) [-0.8]	-0.040 (0.047) [-1.0]
Mean of dep. variable (Within st. dev.)	0.321 (0.167)		
State F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
Month F.E.	No	Yes	No
Month–state F.E.	No	No	Yes
State trends	No	Yes	No
Observations	6,528	6,528	6,528
R <sup>2</sup>	0.470	0.490	0.499

*Notes.* Estimates for all 32 states in Mexico in period 1990–2006. **State trends** is a complete set of linear trends interacted with state indicators. Standard errors clustered at the state level in parenthesis. Standardized effects in brackets. Levels of significance are reported as \*\*\*p<0.01, \*\*p<0.05, \*p<0.1.

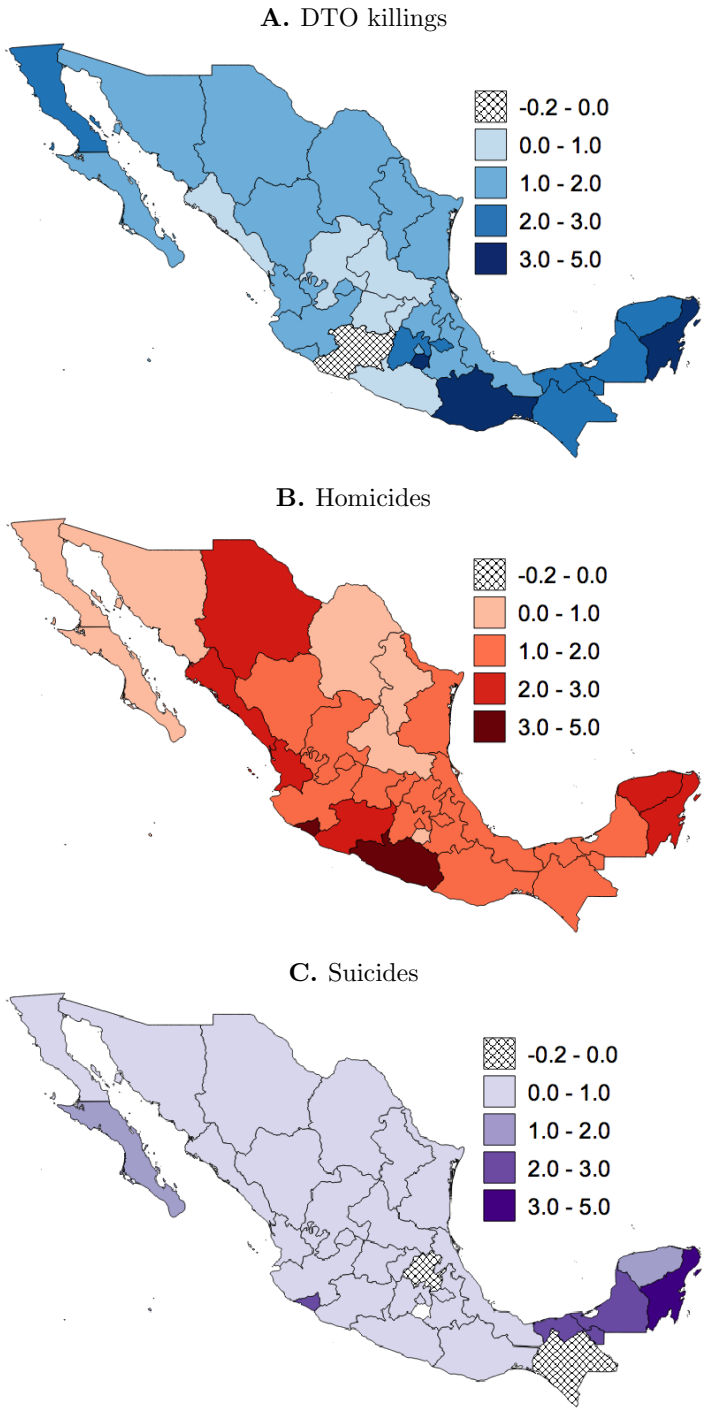


**Figure A.1:** Comparison between Mexico and the U.S.



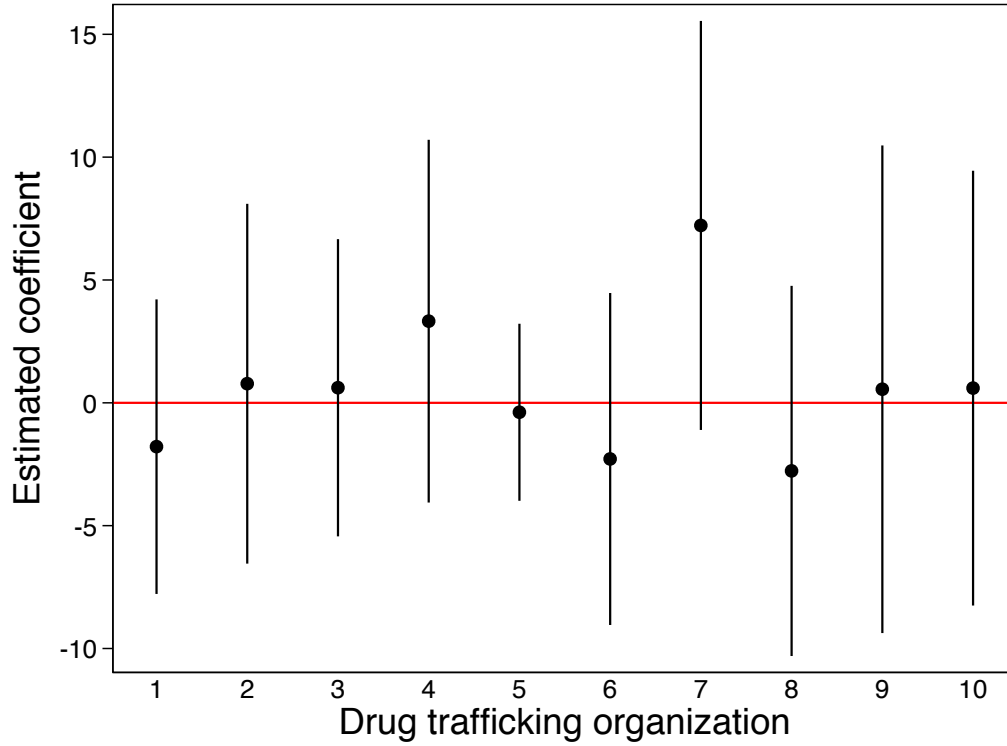
*Notes:* These figures show comparison between death rates per 100,000 inhabitants between Mexico and the United States. In particular, the upper panels show the country comparison in 2011, and the lower panels show the time series variation. Data for the U.S. comes from the United Nations Office on Drugs and Crime (UNODC) and the American Foundation for Suicide Prevention. Data for Mexico comes from INEGI.

**Figure A.2:** Geographic distribution of estimates



*Notes:* Estimated effect of temperature on the outcome of interest for each state in Mexico. Coefficients are expressed as percentage of the average coefficient for comparison across maps. Categories in these maps correspond to intervals of the same size. Darker colors for larger coefficients. States colored in gray indicate a negative estimated coefficient.

**Figure A.3:** Classification of violent DTO

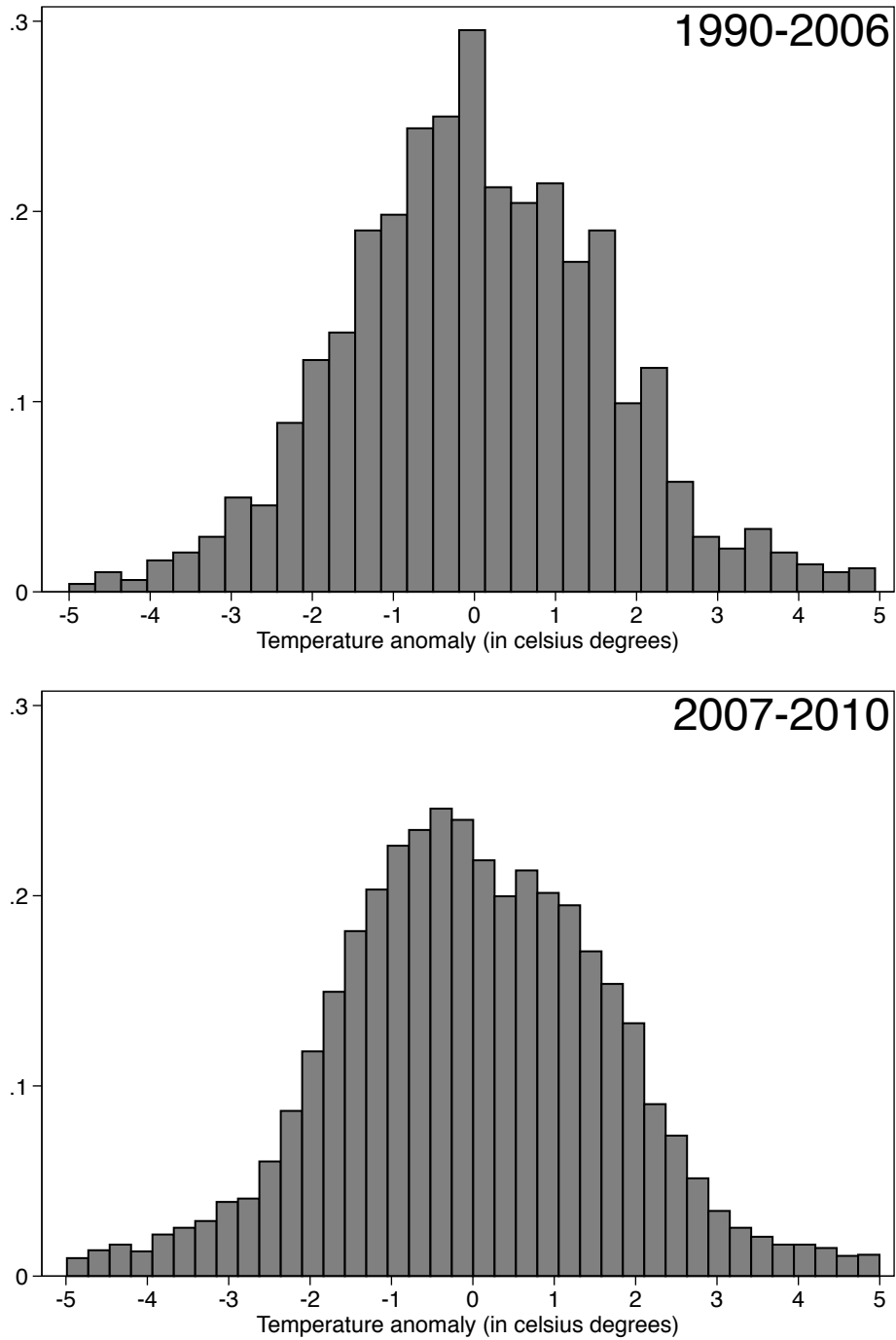


*Notes:* This figure presents estimates  $\beta_k$  of the following equation:

$$y_{st} = \alpha + \lambda_t + \zeta_s + \sum_{k=1}^{10} \beta_k DTO_{kst} + \varepsilon_{st}$$

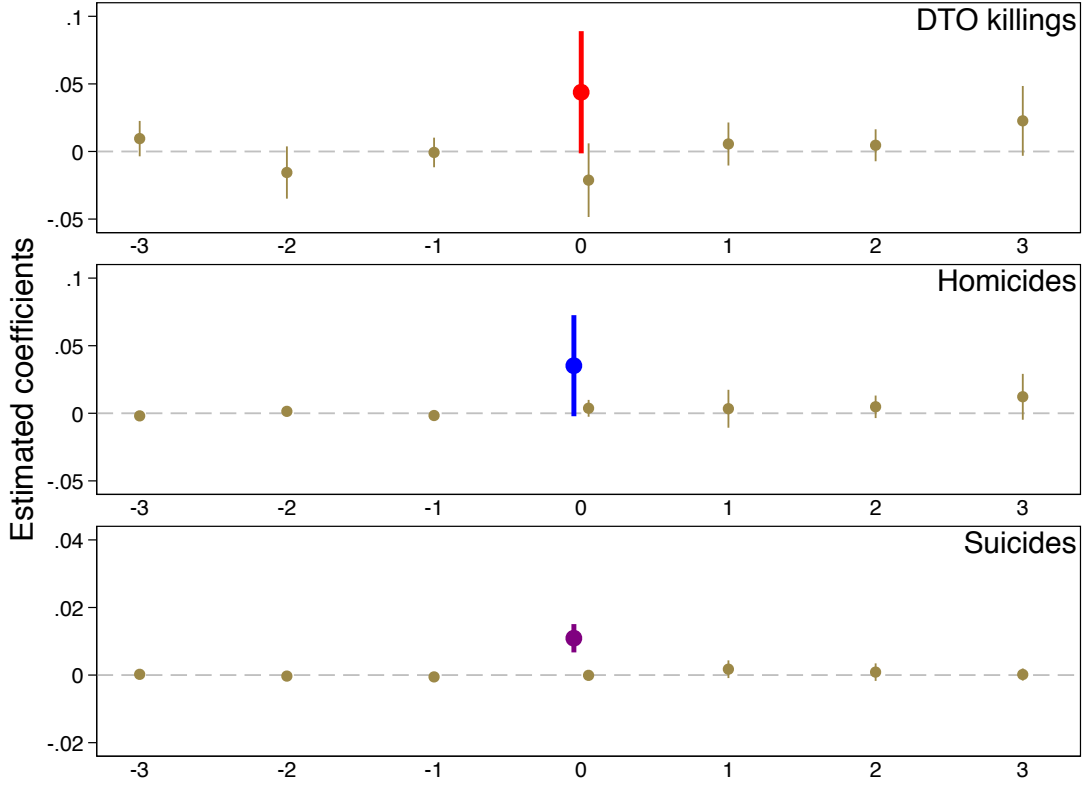
Where  $y_{st}$  is DTO killings for each 100,000 inhabitants,  $\alpha$  is a constant term,  $\lambda_t$  is a year fixed effect,  $\zeta_s$  is a state fixed effect,  $DTO_{kst}$  are ten indicator variables, and  $\varepsilon_{st}$  is an error term clustered at the state level. According to our definition, DTO number 7 is then classified as violent.

**Figure A.4:** Distribution of temperature



*Notes:* This figure presents the distribution of temperature — net of state, year, and month fixed effects— for (A) the period from January of 1990 to December of 2006, and (B) the period from January of 2007 to December of 2010.

**Figure A.5:** Effects of leads and lags of PROGRESA transfers

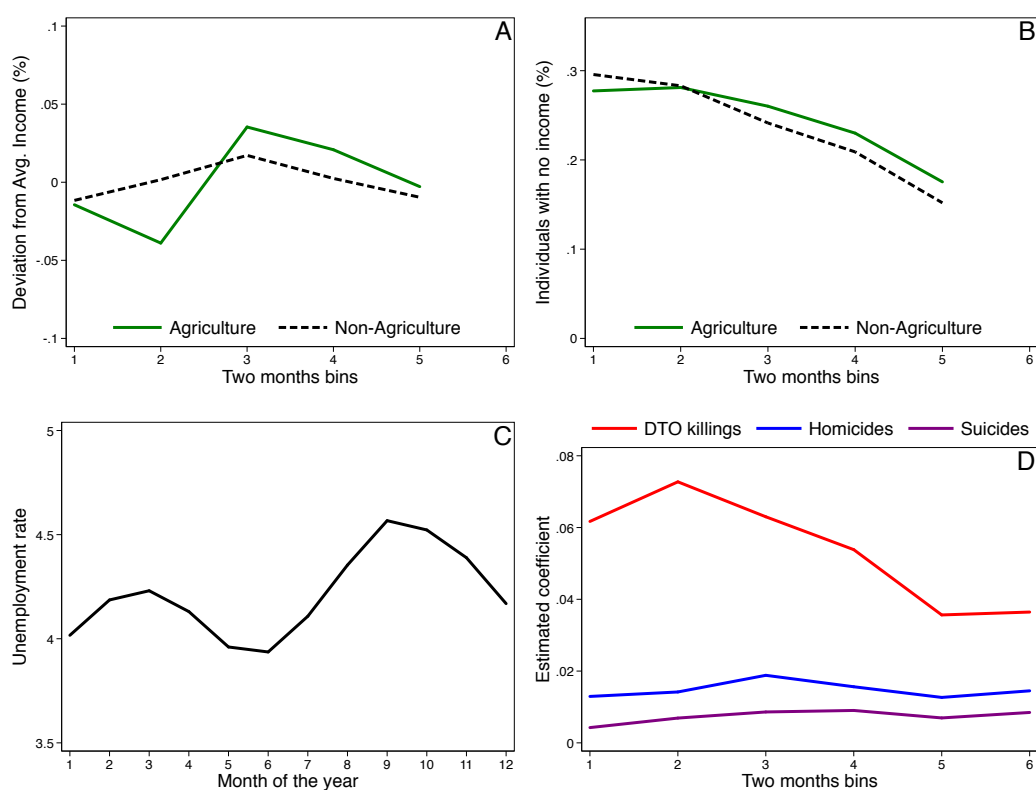


Notes: This figure presents estimates of the following regression:

$$\begin{aligned}
 y_{smt} = & \alpha + \beta \text{Temp}_{smt} + \delta \text{Precip}_{smt} \\
 & + \sum_{k=-3}^3 [\gamma_k (\text{Progresa}_{s(m+k)t} \times \text{Temp}_{smt}) + \phi_k \text{Progresa}_{s(m+k)t}] \\
 & + \lambda_t + \xi_m + \zeta_s + \varepsilon_{smt}
 \end{aligned}$$

where everything is defined as in the main text, and  $\text{Progresa}_{s(m+k)t}$  is the logarithm of Progresa transfers in state  $s$ , month  $m+k$ , and year  $t$ . The main effect of temperature on DTO killings, homicides, and suicides (i.e.  $\beta$ ) is plotted with the corresponding color we use in the paper. In addition, this figure presents the effects of progresa transfers three months before and after, interacted with temperature, i.e.  $(\gamma_{-3}, \gamma_{-2}, \gamma_{-1}, \gamma_0, \gamma_1, \gamma_2, \gamma_3)$ .

**Figure A.6:** Economic variables and estimated effects by month



**A** Deviation (in %) from average wage for agricultural and non-agricultural workers for two months bins (e.g. bin 1 is January and February). Data for November and December is missing. **B** Percentage of individuals with wage equal to zero in agricultural and non-agricultural sectors. **C** National unemployment rate by month using data from the National survey of occupation (*Encuesta Nacional de Ocupación y Empleo*), available monthly since 2005. **D** Estimated effect of temperature in a particular month on the outcome on interest.