Economic Inquiry

EXTREME TEMPERATURE AND EXTREME VIOLENCE: EVIDENCE FROM RUSSIA

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We study the relationship between extreme temperatures and violent mortality, employing novel regional panel data from Russia. We find that extremely hot temperatures increase violent mortality, while extremely cold temperatures have no effect. The impact of hot temperature on violence is unequal across gender and age groups, rises noticeably during weekends, and leads to considerable social costs. Our findings also suggest that better job opportunities and lower vodka consumption may decrease this impact. The results underscore that economic policies need to target vulnerable population groups to mitigate the adverse impact of extreme temperatures. (*JEL* Q54, I14, K42)

"For now, these hot days, is the mad blood stirring."
William Shakespeare, *Romeo and Juliet,* Act 3, Scene 1

I. INTRODUCTION

"[T]he prime time for murder is clear: summertime," states *The New York Times*. Heightened social interactions and the presence of biological and psychological triggers that prompt violence partially explain why, "in the summer months, the bad guys tend to be deadliest" (Lehren and Baker 2009). Global climate change is persistently debated in policy circles and in the media. Beyond the physical changes in the Earth's environment, it is important to examine possible changes in human behavior having social and economic consequences. Documenting the empirical link between rising temperatures and specific social consequences is a crucial, and quite demanding, task.

The most ubiquitous weather-behavior linkage advanced in biology and psychology is the relationship between uncomfortable temperatures and aggressive individual behavior.[1] In the first review of psychological literature, Anderson (1989) claimed that the temperature–aggression relationship is complex, and laboratory experiments fail to provide robust evidence on it. As suggested by the author, more field and within-country studies are needed to document more precisely whether uncomfortable temperature and aggression have a J- or U-shaped relationship. In a J-shaped form, only hot temperatures prompt aggression, while cold temperatures do not affect it, while in a

*The authors thank Jason Lindo (co-editor), three anonymous referees, Richard Frensch, Ali Kutan, Igor Makarov, Milena Nikolova, Mariola Pytlikova, and participants at the ASSA 2019 meeting in Atlanta, IOS/APB/EACES summer academy in Tutzing, and research seminars at IOS Regensburg, Curtin University, and the Laboratory for Economics of Climate Change at HSE Moscow for valuable comments. The authors acknowledge the support from Russian Science Foundation (RSCF) grant no. 19-18-00262.

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1. For reviews, see Anderson (1989), Anderson et al. (2000), and Hsiang, Burke, and Miguel (2013). A growing body of research also suggests that climate change fosters conflict and warfare. For instance, Burke et al. (2009) and Hsiang, Meng, and Cane (2011) show that weather shocks plausibly impact political stability. Burke and Leigh (2010) and Bruckner and Ciccone (2011) document that weather shocks appear to lead to democratization. Dell, Jones, and Olken (2012) show that adverse temperature shocks increase the probability of irregular leader transitions (i.e., coups).

ABBREVIATIONS

RusFMD: Russian Fertility and Mortality Database
WHO: World Health Organization

Economic Inquiry
(ISSN 0095-2583)
Vol. 59, No. 1, January 2021, 243–262
doi:10.1111/ecin.12936
Online Early publication August 18, 2020

U-shaped form, both cold and hot temperatures increase aggression. In economics, the literature has so far focused on the heat-crime relationship and barely examined whether uncomfortably low temperatures affect violent and aggressive individual behavior. The first economic study of the impact of extreme temperatures on crime was presented by Ranson (2014), who analyzed U.S. historical data and uncovered a positive association between hot weather and crime, extrapolating long-term effects for different scenarios. Recently, Blakeslee and Fishman (2018) have also shown that hot temperature increases violent crime in India. By examining the impact of both extremely hot and extremely cold temperatures, our paper offers an important insight to the ongoing discussion in the literature regarding the shape of the temperature–crime relationship. We fill this gap in knowledge by examining the consequences of extreme temperatures in Russia, a country with a wide range of observed temperatures and one of the highest incidence rates of violence.[2]

This paper examines the impact of uncomfortably hot and cold days on violent mortality and its unequal incidence across gender and age groups by exploring a dataset on temperature and violence across 79 regions of the Russian Federation between 1989 and 2015. We draw on the cultural, geographic, and climatic diversity of the Russian Federation to estimate the likely impact of an additional high and low temperature day on violent acts. These are individual violent acts leading to death occurring in the course of daily life interactions, not acts driven by political or social unrest. The relevance of our results cannot be escaped, especially as the effects of change may become more acute, and as suggested by other studies, the impact of hot days on mortality may be greater in developing countries.[3] Violent acts by individuals are hard to predict, so that any information that helps us reduce victimization is important and valuable.[4]

Our paper makes three distinct contributions to the temperature–crime literature. We are the first to examine the temperature–violence relationship in Russia, an upper-middle-income economy with a wide range of observed temperatures and the institutional context that is substantially different from existing studies on the United States. Moreover, we are the first to document that severe cold temperatures do not impact the violent mortality. We also outline in detail the mechanisms behind the relationship between temperature and violence, examine the heterogeneity of the impact by different population groups, and quantify the socioeconomic costs of the temperature–violence linkage. As such, our paper fundamentally revises insights from earlier papers and offers an original contribution to the literature.

Though only the "tip of the iceberg," evaluating the impact on murders overcomes, in part, the underreporting of physical violence and associated consequences, including psychological violence, the latter naturally also being important.[5] We find that days with average temperatures above 25°C lead to an increase in both female and male victims, while days with lower temperatures do not affect violent mortality.[6] The likelihood of victimization during weekends, as opposed to workdays, rises noticeably for females, suggesting different contexts for the emergence of violence. Our findings also suggest that in regions with higher unemployment and with greater consumption of spirits, the likelihood of victimization during hot days is greater. This suggests that improving economic conditions may help to mitigate the harmful effects of temperature shocks.

The remainder of the paper is organized as follows. Section 2 details the conceptual framework underlying the relationship between

2. According to Soares and Naritomi (2010), Russia is burdened by the largest present value social cost of violence from reduced life expectancy as a share of GDP, immediately after Latin America and the Philippines. Our unique dataset allows us to examine violence perpetrated against women and against men across age groups, on weekdays, and on weekends.

3. Burgess et al. (2017) repeat the exercise reported in Deschênes and Greenstone (2011) for India and find that an additional day with temperatures exceeding 36°C leads to a rise in the annual mortality rate in India that is about seven times higher than for the United States. These are computed relative to a day in the 22–24°C range. For the effects of temperature on mortality, see also Karlsson and Ziebarth (2018) for Germany and Otrachshenko, Popova, and Solomin (2017, 2018) for Russia.

4. Hereinafter by "victimization" we mean the process of being victimized or becoming a victim.

5. Cerqueira and Soares (2016) show results indicating that the total welfare cost of homicides in Brazil corresponds to about 78% of Gross Domestic Product, and the yearly welfare cost is about 2.3%.

6. Deschênes and Greenstone (2011) document the relationship between daily temperatures and annual mortality rates, with both relationships exhibiting nonlinearities, with significant increases at the extremes of the temperature distribution. The estimates in Deschênes and Greenstone (2011) suggest that climate change will lead to an increase in the age adjusted US mortality rate of 3% by the end of the twenty-first century.

violence and weather and discusses the earlier literature. Sections 3 and 4 describe the background of our study and data. Methodology and estimation results are presented in Sections 5 and 6, respectively. The last section offers conclusions.

II. CONCEPTUAL FRAMEWORK AND RELATED LITERATURE

A. *Conceptual Framework*

The impact of weather on violence can be explained from both the supply and demand sides. On the supply side, weather may affect the behavior of potential criminals. On the demand side, weather may affect the behavior of potential victims. Below we outline the possible channels on the supply and demand side in more detail.

On the supply side there are three theories that may explain the impact of weather on violence, including economic theory of rational decision making, biological theory, and contact theory.

Becker's model—the canonical model of crime—implies a decrease in crime on hot and cold days, if heat/cold increases the cost of supply of crime. In Becker (1968), an individual's decision to commit a crime is based on rational consideration of the costs and benefits of the act. In this model, the weather is an input that affects the probability of successfully completing a crime and the probability of escaping undetected thereafter. This explanation has empirical support in cases of cold temperatures, since cold weather associated with natural obstacles to violent crime such as lower mobility due to snow drift, closed doors and windows, and so on (Ranson 2014; Vrij, Van Der Steen, and Koppelaar 1994). However, explaining violence also requires going beyond strictly rational explanations as it may occur as an impulse, not just the result of a search for greater individual utility.

The biological explanation is summed up in Simister and Cooper (2005), who suggest that the human body reacts to both extremely cold and extremely hot temperatures by producing stress hormones, including adrenaline, noradrenaline, and testosterone. This leads to the expansion of the blood vessels, increased heart rate and blood pressure, stimulated respiration, focused attention, and heightened anxiety. These same bodily effects are also present when the human body and human brain need to mobilize for action and possible aggression, during stressful or dangerous situations. Noradrenaline is also associated with higher anger levels (Simister and Cooper 2005). Moreover, the interaction of noradrenaline and testosterone fosters aggression (Kemper 1990). Generally, existing epidemiological studies suggest that hot temperatures are more closely related to hormone activation than cold temperatures, as warm clothes reduce the body stress stemming from the cold (Anderson 1989).

Another biological link between weather and violence is psychological. Anderson (1989) suggests that violent crime and aggressive behavior during extreme temperatures are driven by an emotional or instinctive state of arousal of the nervous system. Anderson (1989) argues that both extremely hot and cold temperatures are uncomfortable for the human body, facilitating aggression. However, while the relationship between hot temperatures and violence is supported by early laboratory experiments, as in Baron and Bell (1976), findings related to cold temperatures are inconclusive.[7]

A third possible explanation for the relationship between heat and aggression is an increased frequency in social contacts (Anderson 1989). As people spend more time outside, get together in larger numbers, and go on vacations, opportunities for violent interactions increase. However, Anderson (1987) and Rotton and Frey (1985) find no empirical support for the interactions-violence explanation and suggest that the impact of extreme temperatures on aggression and crime is not necessarily mediated by the frequency of social contacts.

On the demand side, weather may reduce violence by making potential victims more cautious during extreme days. Existing research suggests that people call for police service more often during hot weather (Auliciems and DiBartolo 1995; Brunsdon et al. 2009; Cohn 1993) and less often during cold weather (LeBeau and Corcoran 1990), walk faster during extremely hot (Rotton, Shats, and Standers 1990) and extremely cold days (Liang et al. 2020). The increased level of adrenaline in the blood on hot days may also help a potential victim to either run away from a threat or to use aggression against it (Simister and Cooper 2005). Temperature may also affect

7. This may stem from contradictory effects of neurotransmitters: while the increase in the level of serotonin during cold weather slows aggression down (Reis 1974), another neurotransmitter, acetylcholine, triggers aggression (Myers 1974).

violence via changes in law enforcement. For instance, in periods of hot ambient temperature, police officers tend to be more aggressive toward suspects (Vrij, Van Der Steen, and Koppelaar 1994) and more likely to issue traffic citations (Ryan 2020). However, police officers are also more likely to be assaulted or killed during hot days (Annan-Phan and Ba 2019).

All explanations cited guide our empirical analysis and are naturally interrelated. In fact, according to Pakiam (1981), a multiple causation theory of crime prevails, whereby "anthropological-biological, socio-economic and physical environmental causes are possible, with a crime finally being triggered by appropriate psychological and physiological changes" (p. 185). While we cannot separate the above-discussed mechanisms from each other, the theoretical underpinnings suggest the following hypotheses regarding the impact of hot and cold temperatures on violence:

H1a: *Extremely hot temperature increases violence*.

H1b: *Extremely cold temperature reduces violence*.

B. Existing Literature

External conditions, including weather conditions, have been shown to affect human judgment and facilitate aggression. For instance, in periods of hot ambient temperature, judges make stricter decisions (Heyes and Saberian 2019), strikes and job quits are more frequent (Simister and Cooper 2005),[8] drivers sound their horn more often (Kenrick and MacFarlane 1986), and even baseball pitchers hit batters more often (Larrick et al. 2011; Reifman, Larrick, and Fein 1991).

Early psychological and epidemiological studies suggest a positive correlation between hot temperatures and crime in the United States (Anderson 1987; Rotton and Frey 1985).[9] Rotton and Frey (1985) find a positive correlation between hot temperatures and assaults, while Anderson (1987) suggests that this correlation is stronger for violent crimes against other persons—e.g., murders, rapes, and assaults, than for violent crimes against property—e.g., robbery, burglary, larceny, and motor vehicle theft. Furthermore, Rotton and Cohn (2004) find that in air-conditioned locations aggravated assaults are not as likely during hot weather.

In economics, several studies examine the temperature–crime relationship in the United States.[10] Jacob, Lefgren, and Moretti (2007) and Ranson (2014) have uncovered a positive association between hot weather and different types of crime. Ranson (2014) also suggests that most violent and nonviolent crimes are significantly reduced during cold weather (below 10°F), while murders are not affected. The literature is also inconclusive regarding the effects of precipitation. Ranson (2014) points out that precipitation does not affect murders, rapes, robbery, or larceny, decreases assaults, and increases manslaughter, burglary, and vehicle thefts. Jacob, Lefgren, and Moretti (2007) find that higher precipitation is associated with a reduction in violent crime. Recently, in studying the impact of pollen concentration on the U.S. crime, Chalfin, Danagoulian, and Deza (2019) use temperature and precipitation as additional controls. The authors find that precipitation reduces both violent and property crime. Using data from India, Blakeslee and Fishman (2018) suggest that hot temperature (above 32°C) increases violent crime and precipitation decreases it, while property crime is unaffected by either temperature or precipitation.

The circumstances behind violent acts differ widely, but it is reasonable to consider whether victimization falls more heavily on specific gender and age groups. Multicountry studies show that 15%–75% of all violence against women is perpetrated by a spouse or domestic partner, and is more prevalent on weekends, when family interactions increase (Aizer 2010; Garcia-Moreno et al. 2006; Hidrobo and Fernald 2013; Hindin, Kishor, and Ansara 2008).[11] For Russia, Volkova, Lipai, and Wendt (2015) estimate

8. In the 1960s "U.S. government officials noted that riots were more likely to occur in warmer weather, and subsequent analysis confirmed this relationship" (Dell, Jones, and Olken 2014, 768, who refer to Carlsmith and Anderson 1979; U.S. Riot Commission 1968).

9. For a review of psychological literature on temperature and crime, see Cohn (1990) and Anderson (1989).

10. Burke, Hsiang, and Miguel (2015) conduct a meta-analysis and suggest that extreme temperature and precipitation increase the likelihood of interpersonal and intergroup conflict.

11. Gantz, Bradley, and Wang (2006) and Card and Dahl (2011) find that emotional cues associated with the results in games of professional football in the U.S. increase the rate of at-home violence by men against their female partners. Economic difficulties and excessive alcohol consumption also increase the incidence of domestic violence (Aizer 2010; Bobonis, González-Brenes, and Castro 2013; Carpenter and Dobkin 2011; Hidrobo and Fernald 2013; Luca, Owens, and Sharma 2015).

that 70%–80% of serious violent crimes, and 30%–40% of murders are committed in the family, with upwards of 10,000 women killed by their close partner. Also, analyzing the impact of weather on violence against females may have important implications for human capital and economic development. For instance, to avoid violence female students in India often compromise on the quality of their education by choosing lower-ranked colleges over higher-ranked ones if a travel route to the latter school is safer (Borker 2017).

For different reasons, related or unrelated to gender, older individuals may suffer differential rates of victimization. Otrachshenko, Popova, and Solomin (2017) investigate the impact of days with hot temperature on all mortality causes, as well as cardiovascular-caused mortality, and respiratory-caused mortality. They find that the adult, but not elderly, are the most affected, and people over 60 are relatively less affected. Using data from the 1990s, Soares and Naritomi (2010) find that the incidence of violence in Latin America is concentrated in prime age.[12] The same is true for the United States (Levitt 1999), while Russia has a later age profile, with groups around 40–45 the most victimized.[13] There is, however, evidence that older women may be especially targeted. Miguel (2005) finds that in Tanzania negative income shocks are associated with a large increase in the murder, by relatives, of elderly women, but not other population groups.

Using data for 73 countries, Soares (2006) estimates that each year of life expectancy lost to violence corresponds, on average, to 3.8% of GDP. In Russia, the difference between male and female life expectancies may be a factor, as well as the evolution of relative health status between males and females, with the latter seeing their health degrading more rapidly over time. Cerqueira and Soares (2016) also point out that incorporating heterogeneities such as age and gender has important effects on the estimated welfare cost of deadly violence, leading to a 23% upward correction in total costs.

12. Cerqueira and Soares (2016) explore data from Brazil and find that men in their 20s are about ten times more exposed to homicide than women of similar age. Also, men in their 20s are three times more likely to be victims of homicide than men in their 40s.

13. In Russia, men in their 20s are about five times more exposed than women of the same age, and as exposed as men in their 40s. These are authors' calculations based on the Russian Fertility and Mortality Database (RusFMD 2016).

Therefore, the literature suggests the following hypotheses regarding the heterogeneity of results by gender, age, and work days/weekends:

H2a *Extreme temperatures affect violence against women more strongly than violence against men.*

H2b *Extreme temperatures affect violence against middle-aged and elderly more strongly than violence against younger individuals.*

H2c *The impact of extreme temperatures is stronger over weekends as compared to week days.*

III. BACKGROUND

Russia is an upper-middle income economy with the largest territory in the world and a population over 143 million. After the collapse of the Soviet Union, in 1991, Russia had faced the transitory period till 2000s. This period was characterized by economic reforms and institutional changes, high crime and homicide rates, and high mortality (Kaminski 1996; Schleifer and Treisman 2005).[14] Currently, the homicide rate in Russia is remains the highest in Europe and is almost twice as high as in the United States (United Nations Office on Drugs and Crime 2019).

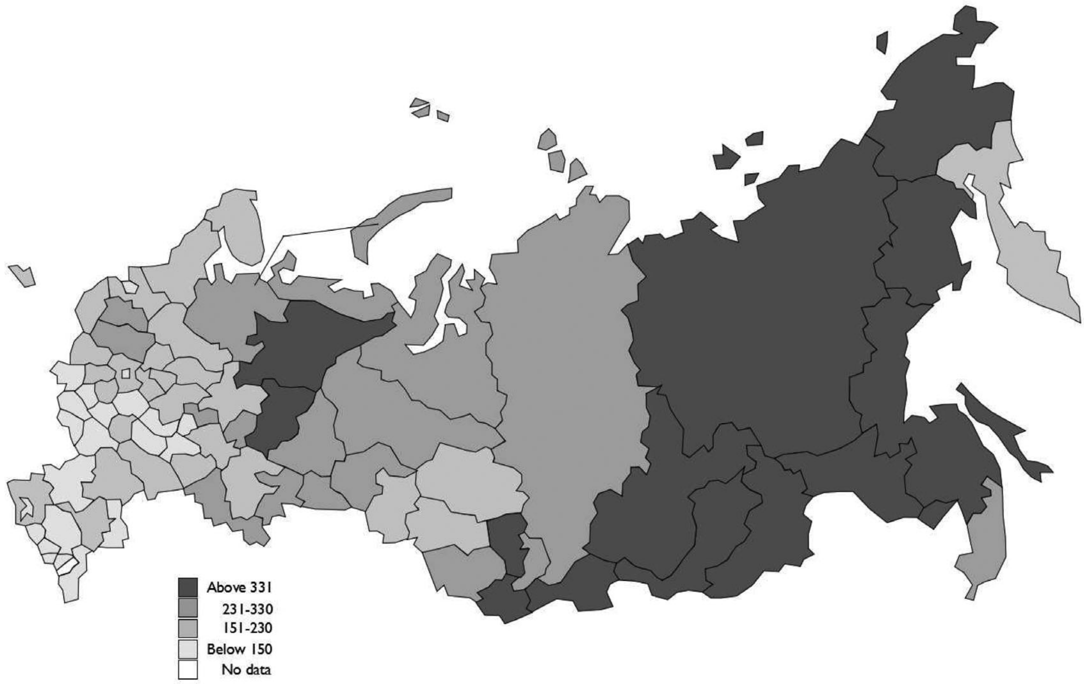
Russian regions are homogeneous in terms of official language, legislation, and law enforcement, but are heterogeneous in terms of climate, homicide rates, and socioeconomic conditions. Figure 1 presents the average annual violent mortality rates per million of population in Russian regions in 1989–2015. As shown in this figure, in the northern European part of Russia and in the most Asian part, the homicide rates are higher than in the central and southern European parts.

Homicide rates also differ by gender and age. Figure 2 presents the violent mortality rates per million of population across gender and age groups in 1989–2015. As shown in this figure, violent mortality is higher among the prime age population, and the homicide rates are higher among males.

The climate of Russia can be predominantly classified as continental in the European part of Russia and subarctic in the Asian part. Summers are warm to hot and winters are very cold in most regions. In the European part of Russia, northern and central regions have mostly dry and

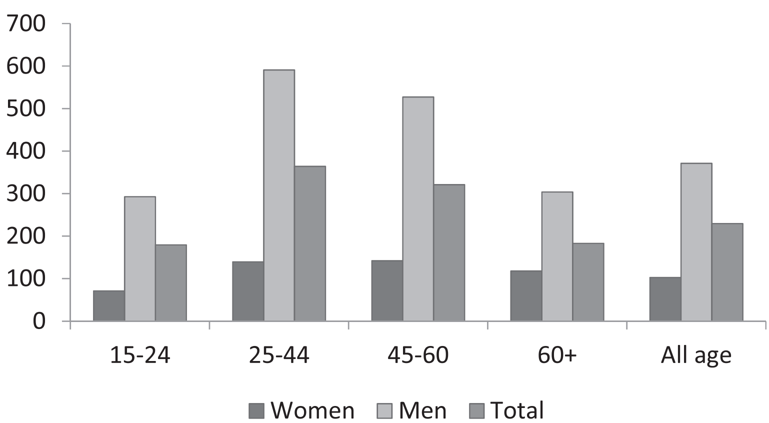
14. To ensure that the transition period does not drive our results, in our robustness checks, we estimate the model for the post-transition period only. The results do not change.

FIGURE 1
Map of Average Annual Violent Mortality Rate in Russia Per Million, 1989–2015



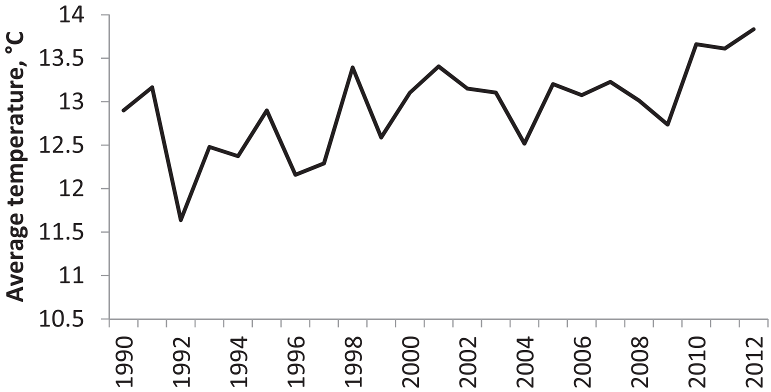
Source: Authors' construction. Computations are based on data from the Federal Statistical Service of the Russian Federation and the Russian Fertility and Mortality Database (RusFMD 2016). Violent mortality rate is measured per million persons.

FIGURE 2
Average Annual Violent Mortality Rate across Gender and Age Groups Per Million—Russia—1989–2015



Source: Authors' computations based on data from the Federal Statistical Service of the Russian Federation and the Russian Fertility and Mortality Database (RusFMD 2016). Violent mortality rate measured per million persons of the corresponding age group is presented.

FIGURE 3
Average Monthly Temperature in June–August in Russia, 1990–2012



Source: Authors' construction based on data from the Climate Change Knowledge Portal of the World Bank.

sunny summers and cold winters with frost and snowfall. In the southern European part, summers are hot and dry, and winters are very cold, except for the areas around the Black Sea, which have mild winters with frequent rainfall. The Siberian part of Russia is known for its extreme weather with very cold winters and hot summers that are short and wet. The coldest place in the central Siberian part is Oymyakon, located in the Sakha Republic, where the winter temperature can be below −55°C in January. Generally, most regions have even precipitation across seasons, except for East Siberia and the Far East, where winter is dry compared to summer.

According to the World Bank the annual average temperature in Russia from 1990–2012 was −5.4°C. The warmest month is July, with the average monthly temperature 15.1°C, while the coldest month is January, with −25.2°C. As shown in Figure 3, the average summer temperature in Russia from 1990–2012 was about 13°C with an upward trend.

IV. DATA

We use annual data on violent mortality rates in 79 regions of the Russian Federation for the period from 1989 until 2015 from the Russian Federal State Statistics Service and the Russian Fertility and Mortality Database (RusFMD 2016).[15] According to the International Statistical Classification of Diseases and Related Health Problems by the World Health Organization (WHO), violent death is defined as a death from homicide and injury purposely inflicted by other persons, including legal execution.[16]

The data on average daily temperature and precipitation are collected from 518 meteorological ground stations and are weighted by an inverse distance square from the nearest population settlement within a 200 km radius. The settlements within a region are then weighted based on their population. Ground stations that are closer to settlements with a larger population thereby receive the largest weight. This approach gives us the weather experienced by an average person in a region (Dell, Jones, and Olken 2014; Hanigan, Hall, and Dear 2006).[17]

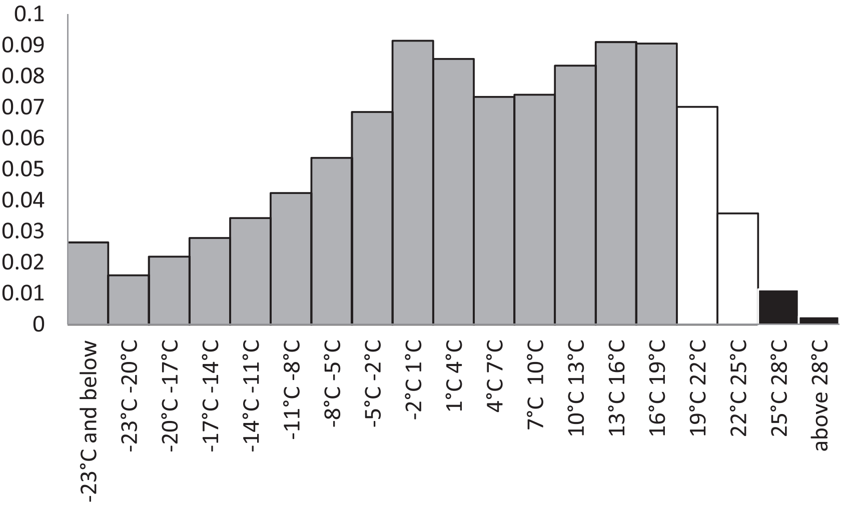
Figure 4 shows the distribution of days with a particular mean daily temperature in Russia from

15. Our dataset includes all regions of the Russian Federation with the exception of autonomous districts that are included in larger territorial units, that is, the Khanty-Mansi Autonomous District—Yugra and the Yamalo-Nenets Autonomous District, which are part of a larger Tyumen oblast, the Nenets Autonomous District, which is a part of the Arkhangelsk oblast. Also, data for the Chechen Republic are not available due to the military conflicts there in the 1990s.

16. The death penalty has been indefinitely suspended and not executed in Russia since 1996. According to archival data, in the period 1991–1996, 163 persons were executed; this is 0.07% of the total violent mortality in Russia during this period.

17. An alternative approach is to use the area-weighted weather data, which gives "the average weather experienced by a place" (Dell, Jones, and Olken 2014, 751). As suggested by Dell, Jones, and Olken (2014), this approach is less preferred for countries with large scarcely populated regions, e.g. the US and Russia.

FIGURE 4
Distribution of Days across Temperature Ranges in Russia, 1989–2015



Source: Authors' computations. *Notes:* The intervals in White, (19°C, 22°C] and (22°C, 25°C], the most comfortable temperature limits, are used as default. The intervals in Black, (25°C, 28°C] and above 28°C, show the extremely hot temperature.

1989 to 2015. As shown in this figure, the temperature spectrum is divided into 3° centigrade intervals. For the empirical analysis, these intervals are constructed for each region and each year. Each interval presents the frequency of days with a particular temperature within a region and year. In Figure 4 the white bars stand for the frequency of days with the (19°C, 22°C] and (22°C, 25°C] temperature ranges, which are the most comfortable temperature limits and used as default. The black bars stand for the frequency of days with the (25°C, 28°C] and above 28°C temperature ranges, showing the extremely hot temperature. Only two thirds of the regions have experienced days above 28°C, and the average number of days with such temperature is 0.97 per year in our sample. Thus, in our analysis, we combine the days above 25°C into one interval.

On average, a day with the mean temperature above 25°C has 33.2°C during the day and 20.1°C during the night. Thus, we consider the days with above 25°C as extremely hot. Regarding the extremely cold days, an average day with the mean temperature below −23°C has −25.6°C during the day and −36.3°C during the night.[18]

18. We also split the temperature bin below −23°C into the [−23°C and − 26°C) and below −26°C temperature bins. The results are similar and are available upon request.

The data on mean daily precipitation within a region and a year are divided into terciles: [0 mm, 10 mm), [10 mm, 20 mm), and between 20 mm and above. The precipitation interval [0 mm, 10 mm) is used as a default. In case of both temperature and precipitation, the numbers of days per year is standardized to 365 days.

Table 1 presents summary statistics on homicide rates and the number of days with extreme temperature and precipitation. As shown in this table, the average number of days with temperature above 25°C is 5.13 per region per year in our sample. Overall, the 25th percentile of regions has experienced 0.93 days above 25°C per year and the 75th percentile of regions has experienced 5.52 such days per year during the period under study. Days below −23°C are more frequent. There are 9.5 such days on average per year with 0.63 days in the 25th percentile of regions and 12.22 days in the 75th percentile of regions. There are also on average 2.05 days with extreme precipitation.

V. METHODOLOGY

To examine the impact of weather on violent mortality, we follow the econometric approach suggested by Deschênes and Greenstone (2011), Burgess et al. (2017), Otrachshenko, Popova, and

TABLE 1
Sample Summary Statistics, 1989–2015

	Mean Across Regions	*SD*	25th Percentile of Regions	75th Percentile of Regions
Number of days above 25°C	5.13	8.31	0.93	5.52
Number of days below −23°C	9.50	17.27	0.63	12.22
Number of days with precipitation above 20 mm	2.05	2.03	0.92	2.96
Total homicide rate, persons per million	229.55	164.64	118.51	290.60
Female homicide rate, persons per million	102.89	68.82	54.22	135.44
Male homicide rate, persons per million	371.08	272.48	192.00	469.60

Source: Authors' computations. All data are averages per year.

Solomin (2017). The econometric model is as follows:

$$(1) \qquad Violence_{rt} = \beta_0 + \sum_{j=1}^{J=17} \beta_j TempBin_{rt} + \sum_{k=1}^{K=3} \delta_k PrecBin_{rt} + \boldsymbol{\alpha_r} + \boldsymbol{\gamma_t} + \boldsymbol{\Phi'}\boldsymbol{\alpha_r} * Trend + \varepsilon_{rt}$$

where the subscripts r and t stand for a region and year, respectively. $Violence_{rt}$ is violent mortality rate per million persons in a region r and year t. The temperature spectrum is divided into 3° centigrade intervals, yielding 17 intervals with a particular temperature: below −23°C, (−23°C, −20°C], (−20°C, −17°C], (−17°C, −14°C], (−14°C, −11°C], (−11°C, −8°C], (−8°C, −5°C], (−5°C, −2°C], (−2°C, 1°C], (1°C, 4°C], (4°C, 7°C], (7°C, 10°C], (10°C, 13°C], (13°C, 16°C], (16°C, 19°C], (19°C, 25°C], and above 25°C. $TempBin_{rt}$ stands for the number of days in a region r and year t in which the mean daily temperature fell in the *j-th* of the 17 intervals. The temperature interval (19°C, 25°C] is used as a default. Similarly, $PrecBin_{rt}$ stands for the number of days in a region r and year t in which the mean daily precipitation fell in the *n-th* of the 3 intervals: [0 mm, 10 mm), [10 mm, 20 mm), and between 20 mm and above. The precipitation interval [0 mm, 10 mm) is used as a default.

$\boldsymbol{\alpha_r}$ are regional fixed effects. The fixed effects estimation controls for region-specific time invariant unobserved factors that may affect regional violent mortality rate, for example, the region-specific quality of medical facilities or characteristics of regional penitentiary system. $\boldsymbol{\gamma_t}$ are time fixed effects that control for time varying factors common across all regions, for example, the health sector or law enforcement reforms. *Trend* is a linear time trend. The interaction term $\boldsymbol{\alpha_r} * \boldsymbol{Trend}$ accounts for any region-specific linear time trends that may affect violent mortality rate and also correlate with climate, for example, trends in regional criminal environment. $\boldsymbol{\varepsilon_{rt}}$ is a stochastic disturbance term while $\boldsymbol{\beta}$, $\boldsymbol{\delta}$, **and** $\boldsymbol{\Phi}$ are the vectors of the model parameters. Standard errors are clustered at a regional level and are robust to heteroskedasticity. We discriminate the impact across gender and age groups and across work days and weekends. Relevant population weights are used for all regressions. We also compute years of life lost by a victim that are due to the impact of one hot day (above 25°C). That is, how many years a victim would live if she/he were not murdered.

Following the recommendation of Dell, Jones, and Olken (2014) and consistently with other studies of the weather-crime relationship (Blakeslee and Fishman 2018; Chalfin, Danagoulian, and Deza 2019; Ranson 2014), we do not include any demographic or economic controls in Equation (1) in order to avoid the "over-controlling problem." As pointed out by Dell, Jones, and Olken (2014), if the model includes controls that are themselves affected by weather indicators directly or indirectly, the estimation does not capture the true net effect of weather indicators and may lead to biased estimates. If economic controls are included in the model the impact of weather is likely to be underestimated. Nevertheless, in our robustness checks we provide a model with the logarithm of gross regional product, unemployment rate, and the level of education proxied by the number of students in higher education.

We provide several additional robustness checks. First, we redefine the size of the temperature bins and divide the temperature spectrum into 6° centigrade intervals instead of 3° intervals. Second, to show that the impact of extreme temperature on violence is contemporaneous, we introduce a distributed lag model with two lags and two leads of temperature bins. Third, we estimate Equation (1) for the post-transition period (2000–2015) only. Next, we include the lagged violence rate in Equation (1), since it might be the case that in regions with high current violence rates, we should expect high violence rates in the next year. Also, we split the above 25°C temperature bin into the 25–28°C and above 28°C temperature bins to investigate whether the impact on violence is greater for higher temperatures. Finally, we estimate a count model, following the empirical strategy suggested by Lindo et al. (2019).

VI. ESTIMATION RESULTS

A. Main Results

In this section we present all results from Equation 1. All regressions are weighted by the corresponding population and robust standard errors are clustered at a regional level.

Table 2 presents the impact of 1 day with a particular temperature range on violent mortality. We find that 1 day with an average temperature above 25°C is associated with a higher prevalence of extreme violence. During a day with temperature above 25°C the number of victims increases by 0.60 persons per million inhabitants. In relative terms, this impact corresponds to 0.26% increase in the total number of victims.[19] This impact of 1 day of hot temperature is also sizeable economically. It might be compensated by 0.35% increase in the regional GDP per capita (see Appendix S1 for details of obtaining this estimate).

As shown in Table 2, we also find no evidence of the impact of cold temperatures. This is an interesting finding, implying that the temperature–violence relationship has a J-shape. This finding also suggests that global warming has two important implications for human well-being: the number of victims may increase not only due to an increasing number of hot days, but also to a decreasing number of cold days. Therefore, we find empirical support for hypothesis H1a, but do not find support for H1b. The results are also presented graphically in Figure 5.

19. The likelihood of being a victim is computed as follows: 0.26% = (0.6 × 100)/229.55. The number in a denominator is taken from Figure 2, while the number in a numerator is taken from Table 2.

TABLE 2
Impact of Temperature on Violent Mortality

	Violent mortality	
	Coef.	**S.E.**
−23°C and below	−0.29	0.50
−23°C −20°C	−0.65	0.61
−20°C −17°C	−0.50	0.84
−17°C −14°C	0.10	0.66
−14°C −11°C	−1.02	0.90
−11°C −8°C	−0.44	0.36
−8°C −5°C	−0.31	0.51
−5°C −2°C	−0.42	0.55
−2°C 1°C	0.03	0.40
1°C 4°C	−0.50	0.47
4°C 7°C	−0.38	0.42
7°C 10°C	−0.30	0.43
10°C 13°C	−0.27	0.35
13°C 16°C	0.08	0.21
16°C 19°C	−0.08	0.26
Above 25°C	0.60***	0.15
10 mm 20 mm	−0.47	0.36
20 mm 100 mm	0.82	1.12
Time fixed effects	Yes	
Regional fixed effects	Yes	
Regional linear trends	Yes	
Number of observations	2,120	
*R*sq-within	0.76	

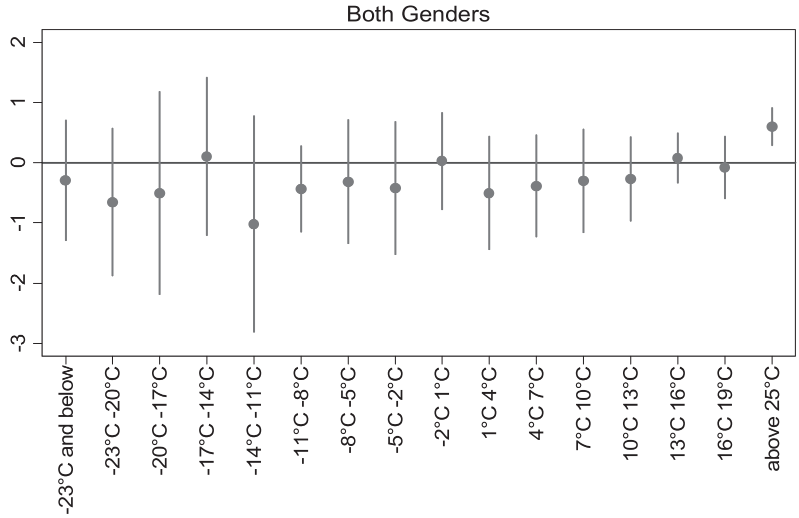
Notes: Coef. and S.E. stand for coefficients and robust standard errors that are clustered at a regional level. All regressions are weighted by the corresponding population. The temperature interval (19°C, 25°C] and the precipitation interval [0 mm, 10 mm) are used as defaults.

***Significant level at 1%.

To establish whether mechanisms through which temperature affects violent mortality are similar to mechanisms that trigger nonviolent mortality, we also analyze the impact of temperature on nonviolent mortality in Table 3. As shown in this table, days with most temperature ranges increase nonviolent mortality.

Furthermore, Figure 6 shows the results on the impact of temperature on the ratio of violent to nonviolent mortality. Interestingly, violent mortality due to hot temperature grows relatively faster than nonviolent mortality. Our results show that this impact is likely driven by the impact of temperature on violence against females (see Figure A1 in Appendix S1). Those findings suggest that mechanisms behind the relationship between temperature and violent and nonviolent mortality are likely to be different. As suggested in earlier literature, in the case of nonviolent mortality, the mechanism is primarily biological. In particular, ambient temperatures beyond comfortable limits induce thermal stress that affects most human biological systems, including cardiovascular, respiratory, and cerebrovascular

FIGURE 5
Impact of Temperature on Violent Mortality.



Notes: The dots represent the estimated coefficients from Table 2 with their 95% confidence interval. All regressions are weighted by the corresponding population. The temperature interval (19°C, 25°C] and the precipitation interval [0 mm, 10 mm) are used as defaults.

(Deschênes and Moretti 2009; Martens 1998). This increases the risk of nonviolent death in case of any uncomfortable temperatures. In the case of violent mortality, the mechanism behind the temperature–violence relationship might be more complex, involving economic, social, and biological mechanisms that are difficult to separate.

We next test possible mediating channels between weather and violence by introducing a set of regional socioeconomic indicators in our baseline specification.[20] As discussed above, including economic controls in Equation (1) may lead to the over-controlling problem since most economic variables are themselves influenced by weather.[21] Thus, we estimate the model with included economics variables only to provide a suggestive evidence on possible mediating channels.

Table 4 presents our results for the four possible mediating channels considered, namely: the natural logarithm of real monthly wage, the rate of unemployment, the consumption of vodka per capita, and the natural logarithm of the regional level of education as measured by the number of higher education students per 1 million of population. As shown in this table, in the model with regional unemployment the impact of hot temperature is lower than in the baseline specification. Thus, unemployment may serve as a mediating channel between temperature and violence. Similarly, vodka consumption reinforces the impact of hot temperature, while the real monthly wage and education do not alter the impact of hot temperature on violent mortality. These findings remain as suggestive evidence of possible mediating channels and can be addressed in greater depth in the future.

B. Robustness Checks

To check that our results are robust, we analyze several alternative specifications. We first redefine the size of the temperature bins. The results remain the same when we divide the temperature spectrum into 6° centigrade intervals

20. We are here limited to the post-1995 period, as data on socioeconomic characteristics are available only after that date.

21. For instance, see Dell, Jones, and Olken (2012) on the impact of temperature on economic growth, Graff Zivin and Neidell (2014) on the impact of temperature on reallocation of time, Park (2020), Park et al. (2020), and Graff Zivin, Hsiang, and Neidell (2018) on the impact of temperature on cognitive performance and educational attainment. As suggestive evidence, Table A1 in Appendix A shows the results with the economic variables included. Including these variables does not affect the main result.

TABLE 3
Impact of Temperature on Nonviolent Mortality

	Nonviolent Mortality	
	Coef.	**S.E.**
−23°C and below	19.58***	4.36
−23°C −20°C	−1.33	6.19
−20°C −17°C	11.42**	4.35
−17°C −14°C	14.80***	4.73
−14°C −11°C	9.45	6.05
−11°C −8°C	7.94*	3.90
−8°C −5°C	10.36***	3.29
−5°C −2°C	9.11*	5.35
−2°C 1°C	8.31***	2.72
1°C 4°C	−0.44	3.32
4°C 7°C	4.41	3.40
7°C 10°C	9.09***	2.57
10°C 13°C	−0.34	2.44
13°C 16°C	1.13	2.44
16°C 19°C	−1.00	3.30
Above 25°C	9.63***	2.69
10 mm 20 mm	−6.84	6.57
20 mm 100 mm	17.75	20.19
Time fixed effects	Yes	
Regional fixed effects	Yes	
Regional linear trends	Yes	
Number of observations	2,120	
*R*sq-within	0.87	

Notes: Coef. and S.E. stand for coefficients and robust standard errors that are clustered at a regional level. All regressions are weighted by the corresponding population. The temperature interval (19°C, 25°C] and the precipitation interval [0 mm, 10 mm) are used as defaults.

***Significant level at 1%.

instead of 3° intervals (see Table B1 and Figure B1 in Appendix S1).

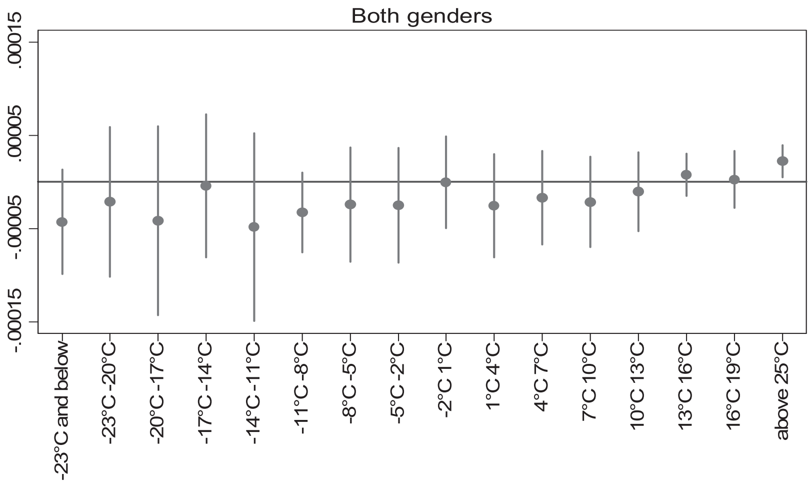
Next, to show that the impact of extreme temperature on violence is contemporaneous, we introduce a distributed lag model with two lags and two leads of temperature bins.[22] It might be the case that unobserved trends in regional crime policies correlate with climate. In this case homicides may rise/fall prior to extreme temperature days. If the model accounts for such trends adequately, then leads in temperature bins should not affect the current-period violent mortality. Also, if it is indeed the immediate lack of comfort due to extreme temperature that causes violence, then the effects should be observed primarily in the year of extreme temperatures, not in the subsequent years, that is, the lagged temperature bins should have no strong effect on violent mortality. As shown in Table B2 in Appendix S1, the estimated coefficients on leads and lags of both extremely hot and extremely cold temperatures do not affect current violent mortality, except for the marginal significance of the coefficient on the previous year hot temperature bin. This indicates that no information is left unexplained in the current-period violence that correlates with the past and future periods' temperature bins. The coefficient on a current-period hot temperature is also quantitatively similar to the one in the main model (Table 2). Thus, the main model adequately captures the impact of weather on violent mortality.

Until 2000 Russia was in a transition period from the communist to market economy that was characterized by institutional development, economic reforms, political changes, and changes in social life. To check the robustness of our results we estimate Equation (1) for the post-transition period (2000–2015) only, and then compare the coefficients with the original model (1). As shown in Table B3 in Appendix S1, in the models with (1) and without (2) a transition period, the coefficients on the above 25°C temperature bin are statistically significant. Even though the magnitude of coefficients in the two models differs slightly, the confidence intervals of the estimates overlap, suggesting that they are not statistically different from each other.

Furthermore, it might be the case that in regions with higher current violence rates, we should expect high violence rates in the next year. For that purpose, we include the lagged violence rate in Equation (1). Model (3) in Table B3 shows that the coefficient on the above 25°C temperature bin is statistically significant. Comparing two models (with (3) and without (1) the lagged variable) we find that in the model with the lagged violence rate the estimated coefficient is smaller when compared to the original model. However, the confidence intervals of the two estimates overlap. As suggested in the economy-climate change literature review by Dell, Jones, and Olken (2014), one should be careful in using endogenous variables in analysis since doing so

22. There is no general rule about how many lags and leads of temperature bins to include in such a model. Deschênes and Moretti (2009) analyze daily data on mortality and extreme temperatures in the US and conclude that the effects of hot temperature (above 80°F or ca. 26.6°C) are short-lived and dissipate within less than 30 days, while the effects of cold temperature (below 20°F or ca. -6.6°C) are longer but also dissipate within at most 90 days. Therefore, we assume that 2 years prior/after the specific temperature occurred is a sufficient time period to capture any changes in violence. Moreover, including more lags and leads of all temperature bins substantially reduces the degrees of freedom in estimating the model. Recently, Schmidheiny and Siegloch (2020) show that distributed-lag models are numerically equivalent to the event study designs with binned endpoints.

FIGURE 6
Impact of Temperature on the Ratio of Violent Mortality to Nonviolent Mortality.



Notes: The dots represent the estimated coefficients on temperature bins with their 95% confidence interval. All regressions are weighted by the corresponding population. The temperature interval (19°C, 25°C] and the precipitation interval [0 mm, 10 mm) are used as defaults.

TABLE 4
Testing for Mediating Channels

Channel		Coef.	S.E.
Baseline	Above 25°C	0.42***	0.14
	Below −23°C	0.11	0.36
	*R*sq-within	0.84	
	Number of observations	1,675	
Real wage	ln(Real wage)	4.39	47.34
	Above 25°C	0.42**	0.16
	Below −23°C	0.16	0.38
	*R*sq-within	0.84	
	Number of observations	1,614	
Unemployment	Unemployment	1.99	2.23
	Above 25°C	0.35**	0.16
	Below −23°C	0.36	0.41
	*R*sq-within	0.82	
	Number of observations	1,867	
Vodka consumption	Vodka consumption	−11.84	10.02
	above 25°C	0.62***	0.13
	below −23°C	−0.79*	0.42
	*R*sq-within	0.91	
	Number of observations	1,258	
Education	ln(Education)	11.95	15.49
	Above 25°C	0.44**	0.16
	Below −23°C	0.17	0.36
	*R*sq-within	0.84	
	Number of observations	1,617	

Notes: Coef. and S.E. stand for coefficients and robust standard errors that are clustered at a regional level. All regressions are weighted by the corresponding population. The temperature interval (19°C, 25°C] and the precipitation interval [0 mm, 10 mm) are used as defaults. All models include all temperature and precipitation bins as in a baseline model, time and regional fixed effects, and linear regional trends. Data are for the post-1995 period.

*Significant level at 10%; **significant level at 5%; ***significant level at 1%.

may lead to biased estimates. This is exactly the case, since the lagged violence also depends on the weather of the previous period. Thus, if the lagged dependent variable is included, the current impact of weather is underestimated.

As stated above, only two thirds of regions are affected by the temperature above 28°C and the annual average number of days with such temperature range is 0.97. It would be interesting to split the above 25°C temperature bin into the 25–28°C and above 28°C temperature bins to analyze whether the impact on violence is greater for higher temperatures. As shown in Table B3, in model (4) with above 28°C temperature bin, the impact of that temperature range is greater than the impact of the above 25°C temperature bin, even though not statistically different. This suggests that the estimates in this study should be considered as lower bounds and if the number of days with higher temperature (i.e., above 28°C) increases, the impact of climate change on violence will be greater.

Finally, we estimate a count model, using the empirical strategy suggested by Lindo et al. (2019). The results are presented in Table B4 in Appendix S1. As shown in this table, one day with an average temperature above 25°C increases the number of violent deaths.

C. Heterogeneity across Age, Gender, and Days of the Week

We then discriminate the impact of temperatures across age and gender groups and work days and weekends. As shown in Table 5, one day with an average temperature above 25°C increases the number of female and male victims by 0.32 and 0.91, respectively. In relative terms, those impacts correspond to 0.31% and 0.245% increase in the number of female and male victims, respectively.[23] The results are also presented graphically in Figure A2 in Appendix S1.

As shown in Table 2, we find no evidence of the impact of cold temperatures. In line with this result, we also find no impact of cold temperatures on males and females in Table 5. Thus, in relative terms, we provide empirical evidence in support of hypothesis H2a, that is, that the female homicide rate is affected by extreme temperature more than the male homicide rate, although only in the case of hot temperatures. This is an interesting finding, suggesting that global warming has two dangerous implications for human well-being: the number of victims may increase due not only to an increasing number of hot days, but also to a decreasing number of cold days.

We further distinguish four age groups: young (15–24 y.o.), adult (25–44 y.o.), mature (45–59 y.o.), and old (above 60 y.o.). As shown in Table 6, 1 day with an average temperature above 25°C is significantly associated with more violence against females and males across all age groups, except for young females. Quantitatively, the impact of extreme weather is greater for males than for females, with young and mature males affected the most.[24] Nevertheless, in relative terms the likelihood of victimization among females is greater—0.9%, 0.88%, and 1% for adults, mature, and old, respectively, when compared to male counterparts—respectively 0.35%, 0.24%, and 0.41%, that is, between one third and one half of female rates. Thus, we find only partial support for hypothesis H2b.

In line with hypothesis H2c, we also find that both males and females are more likely to fall victim in response to temperature shocks during weekends, with victimization rates about three times greater than those during work days for adult females and about two times greater for mature males. The impact of temperature on female victimization is significant and positive for adult, mature, and old females during both work days and weekends (see Table 7). As for men, the coefficient is significantly different from zero for all age groups. Even though males are quantitatively more victimized than females, in relative terms, the likelihood of being a victim during a weekend is greater for females than for males. For instance, one weekend day above 25°C increases the likelihood of being a victim among adult and mature females by 1% and 1.17%, respectively, while among male counterparts this likelihood is 0.37% and 1.06%, respectively.[25] We also find no evidence of an impact of work days versus weekend days

23. The likelihood of being a victim is computed as follows: for females is 0.31% = $(0.32 \times 100/102.89)$ and for males is 0.245% = $(0.91 \times 100/371.08)$. The numbers in a denominator are taken from Figure 2, while the numbers in a numerator are taken from Table 5.

24. An article in *The New York Times* mentions the lower association of females with violence, both as victims and as perpetrators, together with the greater likelihood of being victimized by someone they know, a partner, or a family member (Lehren and Baker 2009).

25. This finding may be explained by high rates of domestic violence. United Nations estimates are that about 14,000 women in Russia are killed annually by their husbands (United Nations 2006). However, since we actually do not observe whether violence happens on work days or on the weekend, this explanation remains merely suggestive.

TABLE 5
Impact of Temperature on Total Homicide by Gender

	Female		Male	
	Coef.	**S.E.**	**Coef.**	**S.E.**
−23°C and below	−0.01	0.22	−0.51	0.82
−23°C −20°C	−0.30	0.35	−1.02	0.94
−20°C −17°C	−0.14	0.37	−0.88	1.38
−17°C −14°C	0.02	0.28	0.30	1.10
−14°C −11°C	−0.47	0.39	−1.55	1.48
−11°C −8°C	−0.24	0.18	−0.60	0.58
−8°C −5°C	0.00	0.22	−0.61	0.85
−5°C −2°C	−0.21	0.23	−0.62	0.93
−2°C 1°C	0.03	0.16	0.07	0.68
1°C 4°C	−0.11	0.18	−0.94	0.80
4°C 7°C	−0.23	0.17	−0.55	0.71
7°C 10°C	−0.10	0.17	−0.51	0.72
10°C 13°C	−0.02	0.15	−0.56	0.58
13°C 16°C	0.04	0.10	0.12	0.34
16°C 19°C	−0.07	0.11	−0.09	0.44
Above 25°C	0.32***	0.07	0.91***	0.27
10 mm 20 mm	−0.12	0.16	−0.90	0.61
20 mm 100 mm	0.35	0.49	1.40	1.87
Time fixed effects	Yes		Yes	
Regional fixed effects	Yes		Yes	
Regional linear trends	Yes		Yes	
Number of observations	2,120		2,122	
*R*sq-within	0.75		0.74	

Notes: Coef. and S.E. stand for coefficients and robust standard errors that are clustered at a regional level. All regressions are weighted by the corresponding population. The temperature interval (19°C, 25°C] and the precipitation interval [0 mm, 10 mm) are used as defaults.

***Significant level at 1%.

with temperature below −23°C on homicide for either gender.

D. Years of Life Lost by a Victim

According to McCollister, French, and Fang (2010), the total social costs of criminal acts consist of tangible and intangible costs. In the case of murders, tangible costs include victim costs (a present value of life time earnings), criminal system costs (i.e., police protection cost, legal and adjudication costs, and the convicted perpetrators' correction costs), and crime carrier costs (productivity losses associated with perpetrators of crimes). Intangible costs include corrected risk-of-homicide costs that are willingness to pay to prevent violence. According to McCollister, French, and Fang (2010), the total social costs of one murder in the United States are about 9 million USD in 2008 prices.

We compute years of life lost by a victim that are due to the impact of one hot day (above 25°C). That is, how many years a victim would live if she/he were not murdered. This measure is equivalent to victim costs suggested by McCollister, French, and Fang (2010) and contributes 8.2% to the total social costs (McCollister, French, and Fang 2010). Our estimates should be considered as a lower bound of the total social costs. The results are in Table 8, in which columns 1–3 correspond to the estimated number of deaths of females, males, and both genders based on the impact of 1 day with temperature above 25°C (hot) from Table 6. Columns 4–6 stand for the years of life lost by a victim of a particular age group. Those columns are based on the statistics of the WHO (2016) on life expectancy of particular age groups. Columns 7–9 stand for the total number years of life lost due to the impact of one hot day.

Table 8 shows that the greatest number of victims associated with 1 day above 25°C is among adult and mature females and males—10 and 8 female victims, and 23 and 25 male victims, respectively. The greatest total number of years lost is observed among the adult females and males, which is the most economically active and reproductive age group. Overall, we find that the total number of years lost among all age groups is 642 and 1,579 for females and

Table 6

Impact of One Day with Temperatures above 25°C and below −23°C by Gender and Age Group

	Both Gender		Female		Male	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Impact of 1 day with temperatures above 25°C						
All ages	0.60***	0.15	0.32***	0.07	0.91***	0.27
Young (15–24)	0.44**	0.16	0.06	0.09	0.80***	0.27
Adult (25–44)	0.76***	0.23	0.46***	0.13	1.06**	0.42
Mature (45–59)	1.19***	0.30	0.55***	0.16	1.93***	0.52
Old (60+)	0.48***	0.16	0.36**	0.13	0.74**	0.31
Impact of 1 day with temperatures below −23°C						
All ages	−0.29	0.50	−0.01	0.22	−0.51	0.82
Young (15–24)	−0.41	0.41	−0.05	0.16	−0.76	0.71
Adult (25–44)	−0.47	0.73	−0.13	0.31	−0.69	1.20
Mature (45–59)	−0.83	0.94	−0.20	0.44	−1.44	1.54
Old (60+)	−0.32	0.47	0.05	0.30	−0.91	0.89
Number of observations	2,120		2,120		2,122	

Notes: The estimated coefficients on the above 25°C bin and the below −23°C bin for a particular age and gender group are from Equation (1). Coef. and S.E. stand for coefficients and robust standard errors that are clustered at a regional level. Regressions for each gender and age group are estimated separately. Each regression includes all temperature and precipitation bins, regional and year fixed effects, and regional time trends, and is weighted by the corresponding population. Full results are available from the authors upon request.

**Significant level at 5%; ***significant level at 1%.

Table 7

Impact of a Work Day and a Weekend Day with Temperature above 25°C by Gender and Age Group

	Both Gender		Female		Male	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Impact of a work day with temperatures above 25°C						
All ages	0.75***	0.18	0.37***	0.09	1.18***	0.31
Young (15–24)	0.74***	0.21	0.02	0.13	1.41***	0.37
Adult (25–44)	0.94***	0.29	0.53***	0.18	1.37**	0.53
Mature (45–59)	1.34***	0.35	0.59**	0.23	2.22***	0.58
Old (60+)	0.60**	0.21	0.46**	0.18	0.91**	0.41
Impact of a weekend day with temperatures above 25°C						
All ages	1.48**	1.55	0.89***	0.25	2.13**	0.93
Young (15–24)	0.69	0.45	0.31	0.23	1.02	0.79
Adult (25–44)	1.82**	0.83	1.40***	0.39	2.20	1.43
Mature (45–59)	3.50***	1.02	1.66***	0.61	5.60***	1.71
Old (60+)	1.04**	0.49	0.63	0.40	1.91*	1.04
Number of observations	2,120		2,120		2,122	

Notes: The estimated coefficients on the above 25°C bin for a particular age and gender group are from Equation (1). Coef. and S.E. stand for coefficients and robust standard errors that are clustered at a regional level. Regressions for each gender and age group are estimated separately. Each regression includes all temperature and precipitation bins, regional and year fixed effects, and regional time trends, and is weighted by the corresponding population. Full results are available from the authors upon request.

*Significant level at 10%; **significant level at 5%; ***significant level at 1%.

males, respectively. We also compute the average number of years lost per victim. According to our results, if not killed, a female victim would live an additional 26.75 years, while a male victim would live 25.06 years more. Thus, even though there are more males than females among the victims at all age groups, except for the elderly, females have a greater cost in terms of years lost per se.

VII. CONCLUSION

The importance of climate change is hard to exaggerate. However, precise estimates of the social consequences of high temperatures are rare. We rely on heretofore unused data from a novel Russian dataset covering three decades of information on temperatures and violent mortality to estimate the impact of hot

TABLE 8

Estimated Number of Victims of One Day with Temperatures above 25°C by Gender and Age Group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Estimated Number of Deaths			Years of Life Lost			Person-Years of Life Lost		
Age Groups	**Female**	**Male**	**Both Gender**	**Female**	**Male**	**Both Gender**	**Female**	**Male**	**Both Gender**
Young (15–24)	1*	9	9	57.2	45.8	51.5	57.2*	412.20	463.50
Adult (25–44)	10	23	33	38.6	29.2	33.9	386	672	1,118.70
Mature (45–59)	8	25	33	25.3	18.2	21.8	202	455.00	718
Old (above 60)	6	6	12	17.2	12.4	14.8	54	40.18	177.60
Total	24	63	87				642	1,579	2,478
Years of life lost per death							26.75	25.06	28.48

Notes: * is based on nonsignificant coefficient. Columns 1–3 are computed by multiplying the estimated impact of 1 day above 25°C from Table 6 by the average regional population of each gender and age group during the 1989–2015 period. Columns 4–6 stand for the number of years of life lost by each gender and age group computed as a difference between life expectancy and the upper age limit of a particular age group. Columns 7–9 are computed by multiplying columns 1–3 and 4–6.

and cold temperatures on violence. We show that the temperature–violence relationship in Russia is J-shaped, that is, extremely hot temperatures increase violent mortality, while extremely cold temperatures have no effect. In contrast, the nonviolent mortality is affected by most temperature ranges. This finding suggests that the mechanisms behind the temperature–violence relationship go beyond the biological explanations that may drive the effect of temperature on nonviolent mortality and may include economic and social factors too. We also uncover that most victimization occurs on weekends for individuals aged between 45 and 59 years old. Males are more often victimized, especially men between 45 and 59 years old, but females are significantly more victimized on weekends.

The consistent relevance of economic conditions, including unemployment and alcohol consumption, as intermediating factors for the impact of weather on violence suggests that we are capturing an important social mechanism that mediates how temperature translates into violence. Our findings suggest that higher unemployment and more widespread vodka consumption may increase the impact of extreme temperatures on violence. However, it is important to note that socioeconomic conditions are only possible mediating channels since they are themselves affected by the weather conditions. Overall, our results imply that the intensity and type of social interactions, which vary across age and gender, and between work days and weekdays, are important factors determining the social cost of temperature shocks. The importance of these results cannot be overstated, especially as the effects of climate change may become more acute.

Our findings might be interesting to policy makers in other regions and countries. First, we find that victimization due to both hot and cold temperature shocks might be mitigated by improving job opportunities in a region. Also, regulating spirits consumption may help to mitigate the harmful impact of weather shocks, though only cold ones. The increasing relevance of climate change, and the vulnerability of developing countries to its effects, calls for further work on the social determinants of victimhood and the gender and age inequalities it generates.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1 Supporting information