EFFECTS OF CLIMATE CHANGE ON GLOBAL CRIME: 2003-2016 PANEL DATA ANALYSIS

by

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ABSTRACT

Climate change is an incredibly pressing issue that is poised to affect the entire global community. While climate change has long had numerous predicted consequences for environmental systems, more research is delving into its impact on human systems. This paper examines the potential effects of climate change on global crime. While this topic has previously been studied on a country or regional level, few analyses employ a global perspective. Using panel data for 139 countries over the period 2003 to 2016, I analyzed the effects of numerous climate change proxies (CO_2 emissions, precipitation, electric power consumption, air pollution, and total greenhouse gas emissions) on thefts and burglaries. Additionally, a dummy variable for country vulnerability to climate change was included to see if there are different effects for countries that are more imminently threatened by climate change. Ultimately, the results of numerous models found no evidence of significant effects from climate change on the global crime rate. If these findings are robust, this suggests encouraging evidence to question the body of literature predicting adverse effects of climate change on crime.

Introduction

According to the latest report from the Intergovernmental Panel on Climate Change (IPCC 2018), at the current rate of global warming, we will likely see global average temperatures increase by 1.5°C between 2030 and 2052. Climate change presents a unique challenge for policymakers around the world because the climate itself is a common good. Effectively, the climate is non-rivalrous and non-excludable, meaning that there are ripe incentives for exploitation. If your country can continue to exploit the environment while all other countries undertake mitigation efforts, then you have won this classic game theory scenario. However, if your country participates in climate change mitigation and other countries offset those efforts by continuing to exploit the environment, then your country is at a great disadvantage and is incurring costs without any benefits. The inherent danger of this second scenario occurring makes countries understandably reluctant to pursue major mitigation efforts.

While climate change is predicted to have a wide range of consequences, an important potential effect of climatic abnormalities lies in the alterations it may cause to human behavior, especially aggressive behaviors. Unfortunately, there has been a strong link found between adverse weather patterns and aggressive behaviors like crime and conflict (Chen 2017). Given the predictions about climate change's effects on future weather patterns, the adverse effects of weather on human behavior are an important point to understand in order to prepare for potential increases in social conflicts worldwide. Additionally, further information and understanding about the human toll of climate change may help countries overcome their reluctance to pursue mitigation efforts.

This paper ultimately asks the question: what are the effects of climate change on worldwide crime? Using panel data for 139 countries over the period 2003 to 2016, I analyzed the effects of numerous climate change proxies on thefts and burglaries. Additionally, I ran models to test whether there are quartile effects of CO2 emissions or GDP on crime rates, as well as a modelled considering the impacts of geographic vulnerability to climate change on island states and equatorial countries. The results of numerous models found no evidence of significant effects from climate change on the global crime rate. If these findings are robust, this work calls into question the body of literature around the effects of climate change and weather on crime and demonstrates the need for further research into this pressing question.

Literature Review

Climate change is predicted to affect not only the quality of the environment, but also access to water, access to food, mortality, migration patterns, and economic security (IPCC 2018; Yang 2008; Alagidede, Adu, & Frimpong 2015; Graff Zivin & Neidell 2014; Abidoye & Odusola 2015). Additionally, some existing research has examined the impact of climatic variation on human behavior. According to a general affective aggression model that focuses on global warming, "temperature is one of several input variables that arouses negative affect, heightens physiological arousal, and primes aggressive thoughts. These variables are described as mediators that increase the probability of aggressive behavior including violent acts (e.g., assault and murder) that come to the attention of law enforcement" (Anderson et al., 2000; Rotton & Cohn, 2003).

Burke et al. (2009) used a panel regression of climate variation and conflict events from 1981 to 2002 to examine the effects of temperature and precipitation on instances of civil war in Africa. Their results indicated that a 1°C increase in temperature correlated with a 4.5 percent increase in civil war in the same year and a 0.9 percent increase in conflict incidence in the next year. Ultimately, a 1°C warming induced a 49 percent relative increase in the incidence of civil war. While these figures alone suggest strong, disruptive effects of unfavorable climatic conditions, they also extrapolated the data on to future predictions of climate change to infer the long-term effects of this relationship. Using climate projections from twenty general circulation models that have contributed to the World Climate Research Program's Coupled Model Intercomparison Project phase 3, they predicted that, on average, warming-induced increase in conflict risks could result in a cumulative additional 393,000 battle deaths by 2030. This research suggests that instances of conflict will increase substantially if global warming continues its upward trend.

Another study of adverse climatic variation on conflict focused on the effects of rainfall changes on social conflict in Africa, which included 6,000 instances of social conflict over the period of 1979 to 2008 such as demonstrations, riots, strikes, communal conflict, and anti-government violence (Hendrix & Salehyan 2012). Using panel data of mean rainfall for each given African country over this time period, their research found evidence that increases in rainfall correlate with more instances of civil war and insurgency conflicts. Furthermore, years with either very high *or* very low rainfall increase the likelihood of all other types of political and social conflict. Violent conflicts were more prevalent in years of abnormally high rainfall, and non-violent events, such as protest and strikes, are almost twice as sensitive to rainfall scarcity as abundance. Just as temperature alterations are expected to cause more conflict, unusual rainfall patterns appear to affect aggression as well. Although there is less consensus about the effects of climate change on rainfall patterns, the evidence above that either abnormally high or low rainfall can adversely affect behavior indicates that climate change is likely to disrupt the current level of conflict in the future.

Crime

Studies of weather influences on crime have shown a pattern of higher temperatures inducing higher crime rates. In both the United States and Japan, increases in temperature (daily maximum and average per month, respectively) had significantly positive effects on nine major categories of crime ranging from non-violent (robbery, burglary, larceny, and vehicle theft) to violent (murder, manslaughter, rape, aggravated assault, simple assault) (Ranson 2014; Takahashi 2017). In the United States, Ranson (2014) found that violent offenses had a positive linear relationship with crime across 2997 counties from 1980 to 2009. Furthermore, based on the observed strength of the relationship between temperature and crime and the IPCC's A1B climate scenario, crime rates for most offenses are predicted to be somewhere between 1.5 – 5.5 percent higher due to climate change by the year 2090 (Ranson 2014). While those figures may seem like a low and slow increase in the crime rate, they represent a rather large increase in aggregate crime. For example, by 2090 New York City alone could stand to see between roughly 2,000 to 6,000 more incidents of theft per year compared with 2014 under these predictions ("Crime rate" 2019). Collectively across the globe and across the years, this translates to an exceptional increase in crime before the end of the century (HI).

Similarly, Takahashi (2017) examined the period from 2009 to 2015 across 47 prefectures of Japan (a total of 3,807 prefectural months) to determine the impact of average temperature and precipitation changes on the nine major crime categories previously mentioned. The results showed that a higher average temperature in a given month had a significantly positive effect on crime. Similar to previous studies (Jacob et al., 2007; Rotton & Cohn, 2003), Takahashi also finds that increased precipitation has a negative effect on the crime rate. The theorized suggestion behind this is that rainfall simply makes people less likely to be outside, which decreases the ability to commit many crimes. For more common crimes (i.e. assault and burglary), the effects were greater than for less common crimes (i.e. murder). Additionally, suicides increased with increases in average temperature, suggesting that both outward and inward social violence may increase with the effects of climate change. Under the RCP2 scenarios from the IPCC, these relationships are predicted to have consequences such as a 2-7 percent increase in murders per year and an increase of roughly 350 to 1500 suicides per year. The fact that a notoriously low-crime country like Japan also appears to be significantly sensitive to climatic abnormalities demonstrates the global impact of climate change as well as the necessity to study this phenomenon further. In areas with more crime or more dramatic impacts from climate change, the predicted damages could be much greater than the relatively well-situated cases of the United States and Japan.

Vulnerability

Numerous variables contribute to climate change vulnerability in a country, such as geographic, economic, and demographic factors. Vulnerability has been identified as one of the most important factors for countries' drive to combat climate change (Bustos, 2018; Sprinz & Vaahtoranta, 1994, So Young & Wolinsky-Nahmias, 2014). Two of the most vulnerable areas in the world are equator-adjacent desert regions and islands, which are predicted to feel some of the most adverse effects of climate change (IPCC 2014; IPCC 2018; Abidoye & Odusola 2015). African states, especially in Sub-Saharan Africa, are likely to face far more dramatic changes to their climate dynamics than areas farther from the equator with more favorable environmental conditions (IPCC 2014). Sub-Saharan Africa's temperature increases, annual precipitation abnormalities, food and water scarcity, and economic losses are expected to be some of the worst experienced worldwide (IPCC, 2014; Abidoye & Odusola 2015). Island nation vulnerability is also expected to be more severe because of a lack of land availability to use for adaptation (e.g. moving away from affected areas) should climatic conditions stray too far from the norm.

Unfortunately, equatorial regions (especially Sub-Saharan Africa) already experience some of the world's highest crime rates (Alfred 2017). Given the established expectations about the relationship between increased climatic variability (i.e. increased temperatures, rainfall changes, etc.) and crime as well as the severity of climate change side effects predicted in vulnerable regions, we should expect to see the strongest effects of climate change in the most geographically vulnerable regions (H2).

Ultimately, this paper aims to contribute to the growing body of literature attempting to assess the impacts of climate change on societal phenomena. Specifically, I attempt to test two hypotheses about the relationship between climate change and crime:

HI: As climate change has increased, instances of crime will have increased as well.

HII: The most extreme effects of climate change on crime will be in countries with the greatest vulnerability to climate change, specifically island nations and more equatorial nations.

These are salient and pressing questions, for if support is found for the above hypotheses, there are dramatic implications for what problems may arise if we continue to exacerbate the effects of climate change. Most crucially, these effects may be felt the most acutely in countries that are already struggling with vulnerability to climate change. Unlike previous research that is primarily focused on specific regions or countries (Abidoye & Odusola 2015; Alagidede, Adu, & Frimpong 2015; Burke et al., 2009; Halicioglu, 2009; Hendrix & Salehyan 2012; Lise, 2006; Mercan & Karakaya, 2015; Ozturk & Acaravci, 2010; Pao & Tsai, 2010; Takahashi, 2017), this research examines the connection between crime and climate change from a global perspective. Using time and country fixed effects, I hope to parse out the relationship between the changes in climatic patterns over the past 15 years and changes in crime.

Data & Methodology

To identify the effects of climate change on crime, I used panel data from 2003 to 2016 for 842 country-years, which includes 139 individual countries or territories. Crime in each country was derived from the United Nations Office on Drugs and Crime ("dataUNODC," n.d.) reports of theft and burglary per 100,000 of the population. Theft and burglary were chosen (as opposed to other options, like violent crimes) because the greater number of observations would be more likely to accurately reflect variation in their occurrence over time. Furthermore, previous studies have demonstrated a precedent for examining lower severity, higher frequency crimes when looking for environmental effects (Rotton & Cohn, 2003; Takahashi, 2017). Besides adding a larger number of cases, this operationalization is sound because often more severe crimes (e.g. murder, rape) are committed by people that already know each other and are proximate, such as romantic partners. If we assume that some of the variation in crime as a result of weather is due to the fluctuating possibility of encountering a criminal in certain weather conditions (Takahashi, 2017), then we should not expect that severe crimes that are frequently perpetrated by those close to the victim regardless of the weather to change dramatically because of climate change (Rotton & Cohn, 2003).

Climate change was proxied primarily by logged kilotons (kt) of CO2 emissions per country per year. There has been a fair amount of work done using logged CO2 emissions as an independent variable (mostly with regards to its impact on economic activity) (Halicioglu, 2009; Lise, 2006; Mercan & Karakaya, 2015; Ozturk & Acaravci, 2010; Pao & Tsai, 2010), but the majority of analyses have been focused on understanding what drives CO2 emissions. Thus, this research contributes to the growing body of literature that aims to understand the consequences of increased CO2 emissions as opposed to the causes. However, several different proxies including PM2.5 air pollution[1], logged total GHG emissions (kt of CO2 equivalent), average precipitation in depth (mm per year), and logged electric power consumption (kWh per capita) per country per year were examined as potential proxies as well. Electric power consumption might initially be suspect for being too highly correlated with CO2 emissions, but Ozturk and Acaravci (2010) find no evidence of a causal relationship between carbon emissions and energy consumption, justifying the inclusion of both variables. Although CO2 is the primary proxy used, the other novel proxy variables were tested to see if there is value to examining other climate change-related variables. The data for all climate change proxies was obtained from the World Bank database.

One notable omission from the climate change proxies is temperature, which has been used frequently as a proxy for climate change (Ranson, 2014; Takahashi, 2017; Burke et al., 2009; Alagidede, Adu, & Frimpong, 2016; Graff Zivin, Hsiang, & Neidell, 2018; Graff Zivin & Neidell, 2014). Temperature was ultimately not used in this study because of challenges with aggregation. In a multinational study, it is conceptually difficult to find an appropriate way to collect temperature data – some countries are so geographically diverse that a country average temperature means nothing (e.g. averaging Alaska and Texas erases much of the meaningful temperature data in the United States), while using too fine-grained of temperature data (e.g. counties averages, latitude and longitude plots, etc.) is not feasible with country-level crime data.

[1] Population exposed to levels of fine particulate matter exceeding WHO guideline value (% of total).

Additionally, many countries fail to collect and/or report temperature data over any significant time scale. Thus, temperature is ill-suited for multinationals studies of climate change.

Ultimately, the variables theft rate per 100,000 people and burglary rate per 100,000 people were used as individual measures of crime, along with the combined variable of total crime rate per 100,000 people, which includes thefts and burglaries. Total crime rate, total theft rate, and total burglary rate were all logged to standardize their distribution. CO2 emissions was the most complete dataset of all the climate change proxy variables, as well as the most logical choice to directly model climate change over time. Consequently, CO2 was used for most regressions, although Table 4 reveals the results of running a regression using all climate change and control variables simultaneously on the total crime rate.

The control variables used were the unemployment rate (UR), the natural log of GDP per capita ($lnGDPpercapita$), the natural log of the country total population ($lntotalpop$), and the natural log of the percent of the population made up of men ages 15-64 ($lnpercent1564male$). These controls are consistent with existing literature on crime (Ranson, 2014; Rotton & Cohn, 2003). One common control that was not included in this study was race (Rotton & Cohn, 2003). While race might be an appropriate control to include in single country or region studies, the global scale of this analysis makes classifying racial categories and obtaining appropriate data infeasible. Furthermore, country fixed effects should address this relatively time-invariant variable.

In order to assess the impacts of climate change on crime, several models were developed. Table 2 in the following section includes the results of four models using the natural log of CO2 emissions (kt) as the independent variable of interest and the set of control variables outlined above. The first model is a simple pooled regression of the variables as shown by equation (1) below:

$$(1)\ lntotalrate = \beta_0 + \beta_1(lnCO2value) + \beta_3(UR) + \beta_4(lnGDPpercapita) + \beta_4(lntotalpop) + \beta_5(lnpercent1564male) + u$$

where $lntotalrate$ represents the total crime rate per 100,000 people in a country, $lnCO2value$ is logged total CO2 emissions (kt) per year in a country, and the previously discussed controls are included. The second model includes the country and year fixed effects and is shown by equation (2) below:

$$(2)\ lntotalrate_{ti} = \beta_0 + \beta_1(lnCO2value_{ti}) + \beta_3(UR_{ti}) + \beta_4(lnGDPpercapita_{ti}) + \beta_4(lntotalpop_{ti}) + \beta_5(lnpercent1564male_{ti}) + \sum \beta_6 YR_t + \sum \beta_7 CTRY_i + u_{ti}$$

where $lntotalrate_{ti}$ represents the total crime rate per 100,000 people in country i in a given year t and $lnCO2value_{ti}$ is the total CO2 emissions (kt) in country i in a given year t. YR_t are year-specific fixed effects that considers any time-specific common trends or effects, such as protests (Bista and Sawyer, 2019). Additionally, $CTRY_i$ are country-specific fixed effects that considers any country-specific common trends or effects, such as regime type. Capturing year and country fixed effects is critical in this analysis. The former allows us to remove the possibility of the crime rate being affected by world events, such as the global recession in 2007-09, while the latter is an important control for country differences in the crime rate. For example, the range for a count of the total burglaries and thefts throughout the country-years sampled here spans from zero reported cases to over 9 million with a standard deviation of roughly 90,000. Therefore, it is important to capture any time or country-specific effects that would dramatically alter the results otherwise. The previously discussed controls are included in the model shown in Eq(2) as well. The third and fourth models are derived from Eq(2), but include a robust estimate of the variance and robust clustering by country, respectively. The third and fourth models were then repeated using the total theft ($lntotaltheftrate_{ti}$) and burglary rates ($lntotalburglaryrate_{ti}$) as the dependent variables, respectively.

Additonally, the log of real GDP variable was broken into four quartiles (25, 50, 75, 95) according to the country distribution in order to examine the heterogeneous impact of CO2 emissions on the crime rate based on GDP. In other words – is the effect of CO2 emissions on crime different at different levels of GDP per capita. Each quartile variable was interacted with logged CO2 emissions to create three interaction terms (labelled GDPCO225, GDPCO250, and GDPCO275, respectively). Each term captures the difference between a particular logged GDP per capita quartile and the base case of the 95th quartile; for example, GDPCO225 captures the crime rate difference between the 25th and 95th quartiles of GDP. Similarly, the log of CO2 emissions was broken into quartiles (25, 50, 75, 95) to capture the potentially heterogeneous effect of CO2 emissions on the crime rate. Each variable (CO2-25, CO2-50, and CO2-75) was compared against the base case of the 95th percentile to determine if different levels of emission experienced different resulting crime rates.

Finally, a dummy variable was created to account for the differential effects of country geographic vulnerability. The dummy variable included a total of 35 out of 139 countries coded as vulnerable (=1) with the base case being not vulnerable (=0). The 35 vulnerable countries were coded as such due to either their proximity to the equator or being an island nation, both of which may experience more acute effects from climate change. This variable enables a test of HII.

Results

The analyses detailed in this paper are attempting to understand the relationship between climate change and crime in countries. As stated previously, this is a pressing question as climate change continues to be exacerbated, and countries around the world will soon have to adapt to the conditions it imposes, if they have not already. The following section outlines the results of multiple models and contributes to the ongoing attempt to measure climate change as a singular entity. Table 1 below shows the summary statistics of the variables.

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Total Crime Rate (logged)	1,348	6.2302	1.6292	0	9.4212
Total Theft Rate (logged)	1,323	5.9242	1.6673	0	9.1124
Total Burglary Rate (logged)	1,119	4.9286	1.9863	0	8.0955
CO2 emissions (kt) (logged)	1,161	10.1655	2.2038	3.7843	15.5716
Electric power consumption (kWh per capita) (logged)	1,021	8.0054	1.1631	4.3446	10.9114
Total greenhouse gas emissions (kt of CO2 equivalent) (logged)	898	11.0922	1.8855	5.0452	15.7957
Average precipitation in depth (mm per year)	288	1125.007	722.8437	51	3240
PM2.5 air pollution	748	87.2412	28.4613	0	100
Unemployment Rate	990	8.2412	5.6926	0.4892	47.5
Real GPD per capita (logged)	1,347	9.1261	1.4232	5.4968	12.1504
Total population (logged)	1,351	15.7953	1.9717	10.4089	20.9708
Percent of population males aged 15-64 (logged)	1,299	3.4889	0.1077	3.1494	4.2003

The main results of this paper are found in Table 2. For the simple pooled regression in Table 2, Column 1 (Eq(1)), logged CO2 emissions were positive and significant at the 0.001 level. While the coefficient is directionally consistent with predictions that increases in CO2 emissions will translate to a greater total crime rate, the coefficient is marginal. A one percentage point increase in CO2 emissions is correlated with a 0.3621% increase in the total crime rate. Table 2, Column 2 shows the results of Eq(2), which includes country-year fixed effects. CO2 emissions are positive but not significant in this model. A Modified Wald test for groupwise heteroskedasticity in fixed effect regression model rejected the null hypothesis of homoskedasticity, so the following models, shown in Table 2, Columns 3-4, include robust standard errors. Column 3 shows the results of Eq(2) with robust standard errors. Column 4 shows the results of Eq(2) with robust clustering. Neither of these models produce significant results for the CO2 value at the 0.05 level, though the coefficients for all models in Columns 1-4 remain in the expected positive direction.

Table 2: CO2 Emissions and Total Crime Rate

OLS				
Dependent Variable	Total Crime Rate	Total Crime Rate	Total Crime Rate	Total Crime Rate
CO2 emissions (kt)	0.3621*** (0.0598)	0.0115 (0.1299)	0.0115 (0.1230)	0.0115 (0.1587)
Unemployment Rate	0.0331*** (0.0063)	0.0226** (0.0072)	0.0226*** (.0068)	0.0226* (0.0105)
Log real GPD per capita	0.7008*** (0.0402)	0.0162 (0.1126)	0.0162 (0.1116)	0.0162 (0.1894)
Log total population	-0.4581*** (0.0667)	0.2403 (0.4567)	0.2403 (0.4564)	0.2403 (0.7476)
Log percent of population males aged 15-64	-3.1462** (0.5482)	7.7072*** (1.1182)	7.7072*** (1.3437)	7.7072*** (2.3383)
Year effects	No	Yes	Yes	Yes
Robust Option	No	No	Yes	Yes
Robust Clustered Standard Errors	No	No	No	Yes
Adjusted R^2	0.6049	0.9418	0.9418	0.9418
Number of Observations	842	842	842	842

Notes:
t statistics in parentheses. *** p<0.001, ** p<0.01, * p<0.05

Table 3, Columns 1 and 2 use Eq(2) with robustness and robust clustering, respectively (similar to Column 3 and 4 in Table 2). However, these models use the logged total theft rate (per 100,000 of the population) as the dependent variable instead of total crime. Table 4, Columns 1 and 2 similarly use Eq(2) with robustness and robust clustering, respectively. These models use the logged total burglary rate (per 100,000 of the population) as the dependent variable. While the results on total theft rate displayed the expected directionality (a positive relationship between CO2 emissions and thefts), burglaries returned an inverted relationship between CO2 emissions and burglary. However, neither total theft nor burglary rates display significance in the CO2 emissions variable.

Table 3: CO2 Emissions and Total Theft Rate

OLS		
Dependent Variable	Total Theft Rate	Total Theft Rate
CO2 emissions (kt)	0.0945 (0.1041)	0.0945 (0.1520)
Unemployment Rate	0.0212*** (0.0055)	0.0212** (0.0078)
Log real GPD per capita	-0.0102 (0.0915)	-0.0102 (0.1569)
Log total population	0.2451 (0.3959)	0.2451 (0.7164)
Log percent of population males aged 15-64	5.6525*** (1.3463)	5.6525* (2.7902)
Year effects	Yes	Yes
Robust	Yes	Yes
Robust Clustered Standard Errors	No	Yes
Adjusted R^2	0.960	0.960
Number of Observations	831	831

Notes:
t statistics in parentheses. *** p<0.001, ** p<0.01, * p<0.05

Table 4: CO2 Emissions and Total Burglary Rate

OLS		
Dependent Variable	Total Burglary Rate	Total Burglary Rate
CO2 emissions (kt)	–0.0220 (0.2140)	–0.0220 (0.2597)
Unemployment Rate	0.0212* (0.0085)	0.0212 (0.0138)
Log real GPD per capita	-0.0254 (0.1557)	-0.0254 (0.2276)
Log total population	0.2013 (0.9749)	0.2013 (1.7754)
Log percent of population males aged 15-64	7.5813*** (2.0196)	7.5813* (3.2775)
Year effects	Yes	Yes
Robust	Yes	Yes
Robust Clustered Standard Errors	No	Yes
Adjusted R^2	0.9503	0.9503
Number of Observations	699	699

Notes:
t statistics in parentheses. *** p<0.001, ** p<0.01, * p<0.05

Two additional analyses were performed in order to understand the effects of climate change variation on crime. First, Table 5 shows the results of an OLS regression of all climate change proxy variables (CO2 emissions, precipitation, electric power consumption, air pollution, and total GHG emissions) on the total crime rate (controls included). None of the climate change proxies returned statistically significant results. Directionally, all variables except for CO2 emissions returned the expected directionality. As the climate change proxies of electric power consumption, air pollution, and total GHG emissions each increase, there is a predicted increase in the total crime rate. Additionally, as the amount of precipitation in a country falls, there is a predicted increase in the total crime rate, which is consistent with previous literature (Takahashi, 2017). CO2 emissions returned an inverted relationship with the total crime rate. However, the number of observations were also reduced to 69 by including all variables, and country-year effects are not accounted for in these models; thus, few, if any, conclusions can be drawn from these results.

Table 5: All Climate Change Proxies and Total Crime Rate

OLS	
Dependent Variable	Total Crime Rate
CO2 emissions (kt)	-0.3658 (0.3126)
Average precipitation in depth (mm per year)	-0.0002542 (0.0001571)
Electric power consumption (kWh per capita)	0.5666 (0.2890)
PM2.5 air pollution	0.0014 (0.0040)
Total greenhouse gas emissions (kt of CO2 equivalent)	0.0883 (0.2402)
Unemployment Rate	0.0241 (0.0190)
Log real GPD per capita	0.7559*** (0.1944)
Log total population	0.2221 (0.2490)
Log percent of population males aged 15-64	-0.2967 (2.1730)
Adjusted R^2	0.7154
Number of Observations	69

Notes:

- PM2.5 air pollution – population exposed to levels of fine particulate matter exceeding WHO guideline value (% of total)
- t statistics in parentheses. *** $p<0.001$, ** $p<0.01$, * $p<0.05$

The second additional layer of analysis involved breaking CO_2 emissions into quartiles to regress on the total crime rate in order to detect whether there are non-linear effects. CO_2 emissions were broken into quartiles (25, 50, and 75, using 95 as the base case) according to the distribution of emissions. This allowed for the examination of different levels of CO_2 emissions on the total crime rate. The positive relationship between CO_2 emissions and crime rates could be higher at higher levels of emissions, and the effect of such a non-linear impact would be masked by measuring the average effect of CO_2 emissions. However, none of the quartile results were significant for this analysis, and all but the 75th quartile displayed inverted relationships between CO_2 emissions and total crime rate.

Table 6: CO_2 Emissions and Total Crime Rate, Quartiles

OLS		
Dependent Variable	Total Crime Rate	Total Crime Rate
CO2 emissions (kt)	0.0115 (0.1587)	-0.0019 (0.1605)
Unemployment Rate	0.0226* (0.0105)	0.0226* (.0105)
Log real GPD per capita	0.0162 (0.1894)	0.0179 (0.1891)
Log total population	0.2403 (0.7476)	0.2276 (0.7412)
Log percent of population males aged 15-64	7.7072*** (2.3383)	7.7009*** (2.3265)
CO2-25		-0.0246 (0.2455)
CO2-50		-0.0416 (0.1796)
CO2-75		0.0119 (0.1552)
Year effects	Yes	Yes
Robust	Yes	Yes
Robust Clustered Standard Errors	Yes	Yes
Adjusted R^2	0.9418	0.9416
Number of Observations	842	842

Notes:

- The 95^{th} quartile is the base case.
- t statistics in parentheses. *** p<0.001, ** p<0.01, * p<0.05

The final piece of this analysis focused on the potential nonlinear impact of climate change vulnerability. The interaction term between logged CO2 emissions and the geographic vulnerability dummy was regressed on total crime rate. The interaction term coefficient was -0.0188, indicating that for countries that are particularly vulnerable to the effects of climate change, increased emissions are associated with a decline in the total crime rate, contrary to expectations (Table 7, Column 2). However, these results were not significant. Finally, the interaction terms between GDP quartiles (25, 50, 75, using 95 as the base case) and CO2 emissions regressed on total crime rate returned positive coefficients. Additionally, the interaction term for CO2 emissions and the 75th GDP quartile regressed on total crime was significant at the 0.05 level. For every 1% increase in CO2 emissions for countries in the 75th quartile of GDP per capita, there is a 0.0117% increase in the total crime rate (Table 8, Column 2).

Table 7: CO2 Emissions and Total Crime Rate, real GDP Quartiles

OLS		
Dependent Variable	Total Crime Rate	Total Crime Rate
CO2 emissions (kt)	0.0115 (0.1587)	-0.0069 (0.1181)
CO2*GDP-25		0 .0105 (0.0138)
CO2*GDP-50		0.0133 (0.0079)
CO2*GDP-75		0.0117* (0.0047)
Unemployment Rate	0.0226* (0.0105)	0.0210*** (.0057)
Log total population	0.2403 (0.7476)	0.2800 (0.4585)
Log percent of population males aged 15-64	7.7072*** (2.3383)	7.4849*** (1.3807)
Year effects	Yes	Yes
Robust	Yes	Yes
Robust Clustered Standard Errors	Yes	Yes
Adjusted R^2	0.9418	0.9416
Number of Observations	842	843

Notes:

- The 95^{th} quartile is the base case.
- t statistics in parentheses. *** p<0.001, ** p<0.01, * p<0.05

Table 8: CO2 Emissions and Total Crime Rate, Vulnerability

OLS		
Dependent Variable	Total Crime Rate	Total Crime Rate
CO2 emissions (kt)	0.0115 (0.1587)	0.0174 (0.1422)
CO2*Vulnerability		-0.0188 (0.2563)
Unemployment Rate	0.0226* (0.0105)	0.0226*** (0.0067)
Log real GPD per capita	0.0162 (0.1894)	0.0166 (0.1108)
Log total population	0.2403 (0.7476)	0.2447 (0.4487)
Log percent of population males aged 15-64	7.7072*** (2.3383)	7.6932*** (1.3707)
Year effects	Yes	Yes
Robust	Yes	Yes
Robust Clustered Standard Errors	Yes	Yes
Adjusted R^2	0.9418	0.9416
Number of Observations	842	843

Notes:

- The 95th quartile is the base case.
- t statistics in parentheses. *** p<0.001, ** p<0.01, * p<0.05

Conclusion

The results of this research demonstrate little significant correlation between climate change and crime rates worldwide. There was no significant support found for either HI or HII once country-year fixed effects were included. Given that much of the extant literature on the predicted effects of climate change estimates some impact on crime, these results are somewhat surprising and highlight the importance of continuing analyses of this topic. If these null results hold validity, then that bears encouraging news for one aspect of the generally dismal subject of climate change. The findings of this research surmise that climate change will have little impact on crime rates for common criminal activities, which is a relatively positive finding. Additionally, this work is an important step in shifting the conversation around climate change research to cross-national analysis. Most research thus far that has yielded significant results has focused on specific countries or regions, but to understand a global issue eventually requires a global-level analysis.

However, there are significant challenges to this area of research worth noting. Measuring ‘climate change’ as a singular entity (but across countries) is a challenging concept that demands constant refinement. Obtaining cross-national data for all variables over a significant time period presented a substantial issue. Climate change is not a swift event, so having more than 15 years of data would broaden the explanatory power of these analyses greatly. Future work on this subject might also include measurements of regional temperatures or other climate change proxies, which were omitted for this research due to focus on country-level variation and lack of available data. Localizing these analyses or generating finer-grained data for climate change variables and crime would likely go a long way to parsing the relationship between these issues. Finally, this research focused on vulnerability as a potential compounding factor, but the operationalization of “vulnerability” certainly merits further consideration. Ultimately, this analysis contributes to the growing body of literature that is working to anticipate the consequences of climate change so that we might be better prepared to target resources to the most pressing concerns.

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