An Empirical Analysis of Typhoons and Crime Rates in Taiwan

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Abstract: Climate change and variability leads to more frequent and more intensive extreme weather events, such as severe storms and droughts. Due to the special geographic location, Taiwan suffers from serious typhoons frequently, which further threaten the social stability and public security. Using detailed daily-county level data, we examine the impact of typhoons on crime rates in Taiwan and find that with respect to weak-intensity strike, medium-intensity strike significantly increases the rate of automobile theft and motorcycle theft. With dynamic model regression, we find that medium- or strong- intensity strike will statistically significantly decrease the crime rate of drug by 0.11 incidents per 100,000 persons.

Keywords: Crime Rates, Typhoon, Typhoon Intensity, Warning

1. Introduction

Many extreme weather events, e.g., droughts, floods and storms, continue to be the result of climate change and variability (IPCC 2012) and potentially threaten the stability and security of societies (Dell, Jones, and Olken 2014). A number of studies have examined the connection between climatic changes and human conflicts (Hsiang, Burke, and Miguel 2013), the link between extreme weather events and civil conflicts (O'Loughlin et al. 2012; Couttenier and Soubeyran 2013), and the correlation between interannual fluctuations in temperature and typhoons and criminal behaviors (Anttila-Hughes and Wetherley 2016). In terms of studies focusing on criminal activities, most results found a robust positive association between high temperatures and crimes (Simon 1992; Jocob, Lefgren, and Moretti 2007; Ransom 2014). Impact analyses of extreme storm on crimes mainly focus on hurricane and cyclone (Zahran et al. 2009; Roy 2010), with few studies focusing on the subject of typhoons (Anttila-Hughes and Wetherley 2016).

Typhoons, also called as West-Pacific hurricanes, are tropical cyclones developing in the western part of the North Pacific Ocean and causing physical damage via heavy rain and intense winds (Anttila-Hughes and Hsiang, 2012). Taiwan is located in a fracture zone in the western Pacific Ocean. In Taiwan, typhoons often bring downpour and landslide, further leading to economic loss, injury, and loss of life (Lin, Shaw, and Ho 2008; Li, Yang, and Shaw 2010). For instance, Typhoon Morakot struck Taiwan in August, 2009, bringing heavy downpour peaking at 2,777 mm. This typhoon caused catastrophic damage in Taiwan, leaving 461 people dead, 192 others missing, and economic loss of roughly US$3.3 billion (Gao 2015).

In general, after big natural disaster the social stability and public security might be weaken. Leitner et al (2011) examine the impact of hurricane Katrina on crimes in Louisiana. A bit different from hurricanes, typhoons struck Taiwan frequently on average by roughly five times per year from 1958-2011, of which 39% directly made landfall on Taiwan. Some psychiatric study has focused on the level of psychological distress in predicting suicide-related symptom after typhoon Morakot (Chang, Chen, Lung 2012). Few studies use econometric methods to investigate the link between typhoon and crime, with none been found in Taiwan. An understudied aspect of typhoon impact assessments on criminal behavior is that the impact from the intensity of typhoon and bringing precipitation is more important than the impact from whether it occurs. We focus on typhoon scale intensity as well as invading days because we expect that a more intense typhoon would cause more damage to the society, which is more likely to induce society unstable, and thus more crimes. In addition, people would respond more negatively when a typhoon has longer invading days.

Based on the above consideration, this paper examines the impacts of typhoon on crime rate and uses daily data of typhoon in Taiwan as an empirical study. This paper contributes to existing literature is that we investigate the effects of temporal and scale measurements of typhoon on crime rates using daily typhoon data.

The remainder of the paper is structured as follows. Section 2 reviews existing literatures on the effects of temperature, precipitation, and extreme weather events on crime. Section 3 describes sources and statistical description on data. Section 4 discusses empirical model structure and estimation results. The last section concludes the paper.

2. Climate-Crime Literature Review

Human conflicts are shown to be strongly related to the global climate (Hsiang, Meng, and Cane 2011). More frequent human conflicts can be attributed to warmer temperatures and more extreme rainfall, here human conflicts include interpersonal conflicts, intergroup conflicts, and institutional breakdown and population collapse (Hsiang, Burke, and Miguel 2013; Hsiang and Burke 2014). In this paper, we mainly focus on the relationship between climate and interpersonal conflicts/violence.

2.1 Impacts of temperature and precipitation on crime

The idea that temperature directly affects the tendency of aggressive behavior toward others can be dated back at least to the Ancient Greeks (Dell, Jones, and Olken 2014). Early study finds that drivers honk less in cars with air-conditioner than those without air-conditioner (Kenrick and MacFarlane 1986). Similar findings have been found by Rotton and Cohn (2004). They point out that in locations with likely air-conditioning the impact of outdoor temperature on criminal assault is considerably weaker. Simon (1992) mentions that increased assaults under warmer temperature due to the fact that higher temperature induces more people stay outside, and thus increases the pool of potential victim and offenders. He also points out that increased property crime can be attributed to more properties left unattended.

Although it is still unclear to explain the physiological mechanism linking temperature and aggression, their causal relationship seems robust across a variety of studies (Hsiang, Burke, and Miguel 2013). Cohn and Rotton (2000) apply time series analysis to examine the relationship between weather, seasonality, and property crime with hourly data. They find a small but significantly positive effect of temperature on property crimes with control of temporal variables. They also find that more property crimes occur on school closing days. Mares (2013) also uses time series methodology to investigate the linkage between climate change and crime using monthly weather and crime data. His findings suggest that anomalously warm temperature leads to higher levels of violence occurred in socially disadvantageous neighborhoods. Besides, a small body of studies uses rigorous panel methodologies to estimate the impact of temperature and precipitation on crime. Jocob, Lefgren, and Moretti (2007) examine the short-run dynamics of crime with a panel of weekly crimes for 116 jurisdictions from 1995-2001. They find that crime rates show negative serial correlation in a span of weeks. They also find that in a given week higher temperature leads to increase the violent crime and property crime, while more rainfall is associated with less violent crime but does not affect property crime. Using standard panel methods, Ranson (2014) examines impact of climate change on crime with a very detailed panel of monthly weather and crime data for 2997 U.S. counties. He finds that higher temperature increases a range of violent crimes. And precipitation does not statistically significantly affect most types of crimes except burglary and vehicle theft. Different from the conclusions of Jocob, Lefgren, and Moretti (2007), Ranson does not find that weather has a lag impact on criminal activity at the monthly level.

Contrast to the impact of temperature on criminal activities, less evidence in the criminology literature has been found to support the link between rainfall and crime, and stronger link may be found in locations where rainfall plays an important role on local income (Dell, Jones, and Olken 2014). Using rainfall as an instrumental variable for the grain price, Mehlum, Miguel and Torvik (2006) document that higher grain price leads to an increase in the property crime in 19th century Bavaria, Germany. More evidence can be found on the impact of extreme rainfall on crime as discussed below.

2.2 Influence of extreme weather events on crime

In addition to impact analysis of temperature and precipitation on criminal activities, a number of studies examine the effects of extreme weather events on human conflicts, such as droughts, floods, and storms. The relationship between droughts and human conflicts are mainly focused on civil conflicts (O'Loughlin et al. 2012; Couttenier and Soubeyran 2013; Harari and La Ferrara 2013). For example, using panel analysis, both Jia (2014) and Kung and Ma (2014) find that drought periods triggered peasant rebellions in rural area in China. In terms of interpersonal conflicts, several studies have shed light on strong effects of drought/flood on crime. Miguel (2005) documents that in drought or flood years in Tanzanian villages the number of witch killing is significantly increased with the argument that food shortage induced by extreme rainfall leads to elimination of the least productive family members. Using a panel of annual-district level data from India, Sekhri and Storeygard (2011) find that negative rainfall shocks lead to increase domestic violence and dowry killing. Blakeslee and Fishman (2016) also use standard panel analysis and find a robust effect of drought on all types of crimes through the channel of agricultural income shocks.

Much of the storm impact analysis has been done on the economic losses, with the findings that higher economic losses are associated with stronger storms (Nordhaus 2010; Hsiang and Narita 2012). And the impact analyses of storm on crime are majorly discussed under the form of natural disaster. For example, Roy (2010) uses the panel method with yearly-district level data to estimate the impact of natural disaster on crime in India. She sets up the indicator variables for the size of natural disaster events which include storms, floods, and earthquakes. She finds that crime rates increased after moderate to big disasters. Some studies find that crime level decreases after natural disaster. Using a yearly-county level panel data, Zahran et al. (2009) estimate the effects of natural disaster (including hurricanes, floods, and droughts) on four crime outcomes with the method of conditional fixed effects negative binomial. Their findings show that in Florida after natural disasters only reported domestic violent crimes increases while other three crime outcomes decline. Leitner et al. (2011) use the time series crime data in Louisiana and find that in regions where evacuees are received during and after Hurricane Katrina the rates of index crimes[1] remain stable or decrease. The most recent study of storm impacts on crime is done by Anttila-Hughes and Wetherley (2016). They use a panel set of yearly-regional crime and climate data in Philippines over the period 1990-2008 and find that warmer temperature increases the murder rate. They also find a lagged positive effect of typhoons on property crime.

[1] The crime data in the study of Leitner et al (2011) are the standardized FBI Uniform Crime Report (UCR) Index Crimes, including murder, rape, aggravated assault, simple assaule, robbery, burglary, larceny theft, and motor vehicle theft.

Based on the above literature review, we have a short summary. First, most studies have focused on the links between climate and crime using weekly, monthly, and yearly data, with few of them use daily crime data, especially in the framework of standard panel analysis. Second, less is known about the impact of typhoons on criminal behavior, except one study done by Anttila-Hughes and Wetherley (2016), which uses the annual-region level data. This might ignore the short-term effect of storms on crimes. Third, no standard econometric analysis has been found on the relationship between tropical cyclones and criminal activities in Taiwan. As what has been discussed in the previous section, Taiwan is a frequently storm-struck area. Some studies have shown that typhoons caused economic damage and life loss in Taiwan (Gao 2015; Li, Yang, and Shaw 2010). Besides the economic side, it is also very important to estimate the impact of typhoons on crime in Taiwan.

3. Data Description

Taiwan is located in the western Pacific Ocean and during 1958 to 2015 was struck on average by 4.88 typhoons per year. Around 38% of those storms directly made landfall on Taiwan, and the other 62% storms passed by the offshore area but still brought rainfall and in turn influences. These strikes have been of varying intensity. In particular we examine this adopting three intensity categorization – weak, medium and strong.[2] The full data cover the period in 1958-2015 and provide a total of 283 tropical storm observations. However, our analysis only covers the period in

[2] According to the classification from <http://typhoon.ws/learn/reference/typhoon_scale>, weak intensity is 34-63 knots, medium intensity represents 64-100 knots, and strong intensity indicates 100 above knots in 10-minute sustained winds.

2006-2015 due to limited crime data, and in this period a total of 55 storms (5.5 storms per year) stroke Taiwan and around 40% of those storms directly made landfall on Taiwan. The proportion of intensity strikes are 36% for weak storms, 42% for medium storms and 22% for strong storms, respectively. The basic tropical storm information is reported in Table 1.

Typhoon characteristics including intensity, maximum wind speed, warning frequency and landing information are collected from Typhoon Database, the Central Weather Bureau in Taiwan (see Table 2). Besides, typhoon usually lowers the temperature and brings heavy rain, and hence daily temperature and precipitation are used to control climate effect itself and the impacts of tropical storms during typhoon period. The Central Weather Bureau in Taiwan reports the precipitation as daily accumulations (mm) and the temperature as daily average (℃), which are also shown in Table 2. These data show that during typhoon season the average amount of precipitation in typhoon period (37.93 mm) is much higher than that in non-typhoon period (9.32 mm), and the variation of precipitation in typhoon period (84.86 mm) is also much greater than that in non-typhoon period (33.38 mm).

In terms of crime rate, daily crime information is collected from National Police Agency, Ministry of the Interior in Taiwan. The crime cases consist of offenses of larceny (burglary, automobile theft and motorcycle theft), offenses of violence (robbery, abrupt taking and rape) and drug offenses, covering 12 counties and cities[3] during the period in 2006-2015. The crime information is reported by means of crime

[3] The 12 counties and cities in Taiwan include Kaohsiung city, Hualian city, Keelung city, Chiayi city, Nanto county, Pingdong county, Taitung county, Taipei city, Tainan city, Taichung city, Hsinchu county and Yilan county.

type, date and location, and it is assembled to daily crime cases in a county or city. Monthly population in each county or city is collected from Department of Statistics, Ministry of the Interior, and daily crime rates[4] are thus calculated in per 100,000 persons. As shown in Table 2, both average and variation of crime rates of burglary, automobile theft and drug in typhoon period are higher than that in full period.

4. Empirical Estimation and Discussion

This study uses daily crime panel data to attempt to measure the effects of typhoon strike on crime rate and hence it considers two specifications: a static model and a dynamic model. The static model presents a contemporaneous relationship between crime rate and typhoon and weather variables while the dynamic model allows that the impacts of typhoon strike might be distributed over future time period. Hence the static effect of typhoon strike on crime rate is estimated by linear panel-data model and the finite distributed lag (FDL) model is used to capture the implications of storms for crime rates beyond the time period. We apply FDL model by assuming that the effects of typhoon strike will be distributed over current period *t*, and 3 future periods, *t+1*, *t+2* and *t+3*. Using daily observations, the FDL model is specified as follows:

[4] Daily crime rate=daily total crime cases/current month population (per 100,000 people).

$$Y_{ct} = \alpha_c + \sum_i \sum_{l=0}^{3} \beta_{it} W_{ic,t-l} + \sum_j \sum_{l=0}^{3} \delta_{jt} T_{jc,t-l} + \gamma_c time_t + \varepsilon_{ct} \quad (1.1)$$

where Y_{ct} is the crime rate per 100,000 persons in county (or city) c at time t; α_c is the region fixed effects; W_{ict-l} is a vector of weather related variables, including daily mean temperature and daily precipitation at current period and 3 lagged periods; T_{jct-l} includes intensity dummy variables and typhoon characteristics, such as maximum wind speed, warning frequencies and landfall at current period and 3 lagged periods; $time_t$ is the regional time trend, and ε_{ct} is the error term. The distributed lag weight β_{it} and δ_{jt} reflect the immediate and lagged impacts in Y_{ct}.

Table 3 and Table 4 report the impacts of typhoon on crime rates estimated by the linear-panel-data model. Three dummy variables are additional considered in this estimation: After Invading, Typhoon Season, and Lunar New Year Month. The variable “After Invading” indicates the following three days after typhoon strike, the variable “Typhoon Season” equals to 1 means that the crime incidents happen during May to November, and the variable “Lunar New Year Month” indicates February when Lunar New Year comes. Comparison between Table 3 and Table 4 shows that typhoon influences on crime rate of larceny is much significant than that on crime rate of violence, and the following discussion over the typhoon effects is mainly on crime rate of larceny.

As shown in Table 3, increasing temperature significantly increases the crime rate of larceny, including burglary and automobile theft. This finding is consistent with previous literature that increased temperature will aggravate the property crime. However, crime rate of motorcycle theft is reduced when temperature increases. It might be for this reason that people in Taiwan prefer to take public transportation to avoid the discomfort of riding motorcycle in cooler weather. Hence the number of motorcycle parked on the street is reduced and the risk of theft is further decreased. Besides, precipitation significantly suppresses the crime against total larceny, automobile theft and motorcycle theft. It might be due to the discouragement for people to go out in rainy days.

Let's turn now to the analysis of typhoon impacts. With respect to weak-intensity strike, medium-intensity strike significantly increases the crime rate of larceny, especially automobile theft and motorcycle theft. One possible reason to explain this finding is that the public and the police department pay much more attention to preparing for the approaching typhoon and release guard against theft. On the other hand, strong-intensity strike enlarges the crime against motorcycle theft. Nevertheless, strong-intensity strike significantly reduces the crime rate of burglary by at least 0.0537 per 100,000 people. This finding can be inferred from the suspension of work and school and people therefore stay at home when strong-intensity typhoon strikes Taiwan.

The Central Weather Bureau in Taiwan starts to issue warnings every three hours when typhoon is likely to strike Taiwan, and therefore the length of typhoon strike can be characterized by warning frequency. As shown in Table 3, longer typhoon period leads to higher crime rate of automobile theft and motorcycle theft while it results in lower crime rate of burglary.

The impacts of temperature and precipitation on crime rate of violence and drug have similar results as it on crime rate of larceny. Yet typhoon related variables nearly have no significant influence on this crime category as shown in Table 4.

Table 5 reports the estimation results from FDL model which shows the dynamic climate and typhoon impacts. The one degree Celsius increase in temperature significantly decreases the crime rate of larceny in the concurrent day but aggravates the crime rate of larceny in the following days. On the other hand, the crime rate of violence is aggravated by one degree Celsius increase in temperature in the same day but it is reduced in the following days. The crime rate of drug has the same trend with the crime rate of violence. Besides, Table 5 shows that an additional millimeter precipitation seems have inhibitory effects on the crime rates of larceny, violent, and drug. For example, the crime rates of larceny and drug decreases by 0.0005 and 0.0006 incidents per 100,000 people, respectively. It might because rainfall reduces the willingness of criminal to go out to commit a crime.

The impacts of typhoon characteristics, including medium, strong, warning frequency, maximum wind speed and landfall, are also reported in Table 5. The medium and strong dummy variables indicate the intensity of typhoon strike. Medium- or strong- intensity strike will significantly decrease the crime rate of drug by at least 0.11 incidents per 100,000 people. In the category of crime rate of larceny, the current period medium-intensity strike and the three lagged period strong-intensity strike increase the crime rate of motorcycle theft, and it might because that people will pay less attention to their motorcycles parking on the street when typhoon strikes. On the other hand, three lagged period of both medium- and strong-intensity strike reduce the incidents of automobile thefts and total larceny. One way to explain the suppression of crime rate of automobile thefts and total larceny might be that people usually stay at home during typhoon strike and so the thieves have less chance to commit the crime. For the crime rate of violence, only one lagged period medium-intensity strike have positive impacts, especially on the crime of abrupt taking.

5. Conclusion

This study analyzes the impacts of typhoon strike on crime rate using daily crime panel data in 2006-2015 in Taiwan. Our results show that increasing temperature significantly increases most of the crime rates except for motorcycle theft, and precipitation has suppression effect on the crime rates of total larceny, total violence, automobile theft motorcycle theft, drug, and abrupt taking. This finding is consistent with previous literature. Besides, typhoon strike has significant influences on crime rates through intensity, warning frequency, maximum wind speed, and landfall characteristics. For example, medium-intensity strike significantly increases the crime rate of larceny, especially automobile theft and motorcycle theft.

Strong-intensity strike enlarges the crime rate of motorcycle theft by around 0.078

per 100,000 people while it significantly reduces the crime rate of burglary by at least 0.0537 per 100,000 people.

Estimation from FDL model shows the dynamic climate and typhoon impacts. The increase in temperature significantly decreases the crime rate of larceny in the concurrent day but aggravates the crime rate of larceny in the following days while it aggravates the crime rate of violence in the same day but reduces the crime rate of violence in the following days. On the other hand, three lagged period of both medium- and strong-intensity strike reduce the incidents of automobile thefts and total larceny. Therefore the exogenous shock typhoon strike has been proved to have significant impacts on crime rates in this study.

Table 1 Numbers of Tropical Storm Striking Taiwan Between 1958 and 2015

Category	Full Period (1958-2015)			Sub Period (2006-2015)		
	Strike Numbers (%) (A)	Direct Landfall Numbers (%) (B)	(B) / (A) (%) (C)	Strike Numbers (%) (D)	Direct Landfall Numbers (%) (E)	(E) / (D) (%) (F)
Weak (34-63 knots)	71 (25.09%)	21 (19.44%)	29.58%	20 (36.36%)	5 (22.73%)	25.00%
Medium (64-100 knots)	123 (43.46%)	49 (45.37%)	39.84%	23 (41.82%)	10 (45.45%)	43.48%
Strong (>100 knots)	89 (31.45%)	38 (35.19%)	42.70%	12 (21.82%)	7 (31.82%)	58.33%
Period Total	283	108	38.16%	55	22	40%
Yearly Average	4.88	1.86	-	5.5	2.2	-

Source: Typhoon Database, the Central Weather Bureau in Taiwan.

Table 2 Descriptive Statistics of Crime, Typhoon and Weather Data in 2006-2015

		Obs.	Mean	Std. Dev.	Min	Max
Full-period	Temperature (℃)	43619	23.52	4.84	7.10	33.30
	Precipitation (mm)	43442	6.93	26.77	0	1165.50
	Crime against Larceny [a]	41714	0.778	0.598	0	8.798
	Burglary [a]	41714	0.203	0.268	0	2.939
	Automobile Theft [a]	41714	0.460	0.496	0	8.611
	Motorcycle Theft [a]	41714	0.115	0.182	0	2.608
	Crime against Violent [a]	41714	0.047	0.100	0	1.691
	Robbery [a]	41714	0.012	0.050	0	1.268
	Abrupt Taking [a]	41714	0.021	0.064	0	1.471
	Rape [a]	41714	0.014	0.054	0	1.107
	Crime against Drug [a]	41714	0.436	0.417	0	7.730
Typhoon-season [b]	Temperature (℃)	25560	26.418	3.109	10.70	33.30
	Precipitation (mm)	25673	9.324	33.375	0	1165.50
Typhoon-period	Temperature (℃)	2115	27.241	2.368	15.50	31.90
	Precipitation (mm)	2123	37.929	84.856	0	1165.50
	Intensity-Medium	55	0.418	0.498	0	1
	Intensity-Strong	55	0.218	0.417	0	1
	Warning Frequency	55	19.545	8.768	7	54
	Maximum Wind Speed (m/s)	55	38.145	11.903	18	55
	Crime against Larceny [a]	2030	0.807	0.612	0	5.911
	Burglary [a]	2030	0.215	0.285	0	2.226
	Automobile Theft [a]	2030	0.487	0.521	0	5.140
	Motorcycle Theft [a]	2030	0.105	0.166	0	1.179
	Crime against Violent [a]	2030	0.045	0.096	0	1.095
	Robbery [a]	2030	0.010	0.045	0	0.512
	Abrupt Taking [a]	2030	0.020	0.058	0	0.651
	Rape [a]	2030	0.014	0.055	0	0.589
	Crime against Drug [a]	2030	0.460	0.433	0	3.368

Source: the Central Weather Brueau in Taiwan.
a: It reports crime rates per 100,000 persons.
b: Typhoon season covers from May to November each year.

Table 3 Estimation Results on Crime rate of Larceny Regressions (Fixed-Effects Model)

Variables	Burglary		Automobile Theft		Motorcycle Theft		Total Larceny	
Temperature	0.0012* (0.0006)	0.0015 (0.0009)	0.0027** (0.0009)	0.0071*** (0.0014)	-0.0014*** (0.0003)	-0.0008** (0.0003)	0.0024* (0.0012)	0.0078*** (0.0017)
Precipitation	0.0001 (0.0001)	0.0001 (0.0001)	-0.0004*** (0.0001)	-0.0004*** (0.0001)	-0.0001*** (2.23e-05)	-0.0001*** (2.3e-05)	-0.0004*** (0.0001)	-0.0003*** (0.0001)
Medium	-0.0073 (0.0210)	-0.0076 (0.0210)	0.1152** (0.0432)	0.1170** (0.0440)	0.0281*** (0.0078)	0.0283*** (0.0078)	0.1360** (0.0520)	0.1378** (0.0527)
Strong	-0.0537* (0.0269)	-0.0542* (0.0269)	0.0590 (0.0548)	0.0604 (0.0558)	0.0780*** (0.0126)	0.0781*** (0.0127)	0.0833 (0.0639)	0.0842 (0.0649)
Warning Frequency	-0.0027** (0.0009)	-0.0027** (0.0009)	0.0032* (0.0016)	0.0032* (0.0016)	0.0012** (0.0004)	0.0012** (0.0004)	0.0017 (0.0024)	0.0017 (0.0023)
Maximum Wind Speed	0.0014** (0.0006)	0.0014** (0.0006)	-0.0035** (0.0014)	-0.0034** (0.0014)	-0.0014*** (0.0003)	-0.0014*** (0.0003)	-0.0035* (0.0017)	-0.0034* (0.0017)
Landfall	0.0470 (0.0283)	0.0468 (0.0282)	0.0645** (0.0229)	0.0626** (0.0233)	-0.0147*** (0.0044)	-0.0150*** (0.0045)	0.0971* (0.0475)	0.0944* (0.0476)
After Invading	0.0009 (0.0053)	0.0020 (0.0042)	0.0750*** (0.0153)	0.0804*** (0.0162)	0.0015 (0.0055)	0.0024 (0.0054)	0.0773*** (0.0153)	0.0848*** (0.0164)
Typhoon Season		-0.0100 (0.0093)		-0.0312** (0.0112)		-0.0060 (0.0040)		-0.0472** (0.0156)
Lunar New Year Month		-0.0230*** (0.0065)		0.1027*** (0.0113)		0.0092 (0.0072)		0.0889*** (0.0160)
Time	-0.0001*** (1.03e-05)	-0.0001*** (1.03e-05)	2.15e-05 (1.85e-05)	2.25e-05 (1.87e-05)	-3.4e-05*** (6.03e-06)	-3.38e-05*** (6.00e-06)	-0.0001*** (3.09e-05)	-0.0001*** (3.1e-05)
Constant	0.3828*** (0.0216)	0.3820*** (0.0229)	0.3588*** (0.0389)	0.2630*** (0.0498)	0.2108*** (0.0125)	0.1980*** (0.0093)	0.9524*** (0.0622)	0.8429*** (0.0708)

Note: The values in the parenthesis are robust standard errors. * p<0.1, ** p<0.05 and *** p<0.01.

Table 4 Estimation Results on Crime rate of violence and Drug Regressions (Fixed-Effects Model)

Variables	Drug		Robbery		Abrupt Taking		Forcible Rape		Total Violent	
Temperature	0.0060*** (0.0008)	0.0070*** (0.0011)	0.0001 (4.25e-05)	0.0001 (0.0001)	0.0004*** (0.0001)	0.0006** (0.0002)	0.0002** (0.0001)	0.0003** (0.0001)	0.0006*** (0.0002)	0.0010*** (0.0003)
Precipitation	-0.0005*** (0.0001)	-0.0005*** (0.0001)	-1.17e-05 (7.46e-06)	-1.13e-05 (7.52e-06)	-0.0001* (2.47e-05)	-4.77e-05* (2.35e-05)	-3.09e-06 (1.14e-05)	-8.82e-07 (1.11e-05)	-0.0001* (3.6e-05)	-0.0001 (3.42e-05)
Medium	-0.1097*** (0.0315)	-0.1096*** (0.0314)	3.7e-05 (0.0028)	4.53e-05 (0.0028)	0.0043 (0.0043)	0.0044 (0.0043)	0.0007 (0.0053)	0.0007 (0.0053)	0.0050 (0.0077)	0.0051 (0.0077)
Strong	-0.1111** (0.0441)	-0.1113** (0.0441)	0.0058 (0.0052)	0.0058 (0.0052)	0.0027 (0.0070)	0.0026 (0.0070)	0.0046 (0.0072)	0.0047 (0.0072)	0.0131 (0.0146)	0.0131 (0.0145)
Warning Frequency	-0.0009 (0.0009)	-0.0009 (0.0009)	-5.17e-05 (0.0001)	-0.0001 (0.0001)	0.0001 (0.0002)	0.0001 (0.0002)	0.0001 (0.0001)	0.0001 (0.0001)	0.0002 (0.0004)	0.0002 (0.0004)
Maximum Wind Speed	0.0016 (0.0011)	0.0016 (0.0011)	-2.8e-05 (0.0001)	-2.75e-05 (0.0001)	-0.0001 (0.0002)	-0.0001 (0.0002)	-0.0002 (0.0002)	-0.0002 (0.0002)	-0.0003 0.0003	-0.0002 (0.0003)
Landfall	0.1005*** (0.0171)	0.1000*** (0.0170)	-0.0009 (0.0020)	-0.0009 (0.0020)	-0.0080** (0.0031)	-0.0081** (0.0032)	0.0021 (0.0025)	0.0021 (0.0025)	-0.0067 (0.0050)	-0.0069 (0.0050)
After Invading	0.0035 (0.0061)	0.0054 (0.0068)	0.0001 (0.0014)	0.0001 (0.0013)	-0.0006 0.0013	-0.0003 (0.0014)	0.0010 (0.0010)	0.0011 (0.0010)	0.0005 (0.0017)	0.0010 (0.0017)
Typhoon Season		-0.0140 (0.0104)		-0.0002 (0.0008)		-0.0023 (0.0015)		-0.0006 (0.0007)		-0.0031 (0.0021)
Lunar New Year Month		-0.0028 (0.0107)		0.0004 (0.0012)		0.0005 0.0015		0.0037** (0.0013)		0.0046** (0.0017)
Time	-0.0002*** (1.97e-05)	-0.0002*** (1.97e-05)	-6.71e-06*** (8.32e-07)	-6.70e-06*** (8.30e-07)	-1.61e-05*** (3.37e-06)	-1.61e-05*** (3.36e-06)	-2.94e-06** (9.52e-07)	-2.91e-06** (9.55e-07)	-2.58e-05*** (4.24e-06)	-2.57e-05*** (4.24e-06)
Constant	0.6011*** (0.0368)	0.5843*** (0.0349)	0.0230*** (0.0017)	0.0226*** (0.0019)	0.0409*** (0.0049)	-1.61e-05*** (3.36e-06)	0.0156*** (0.0028)	0.0128*** (0.0033)	0.0795*** (0.0074)	0.0730*** (0.0076)

Note: The values in the parenthesis are robust standard errors. * p<0.1, ** p<0.05 and *** p<0.01.

Table 5 Estimation Results from Finite Distributed Lag Model

Variables	Crime rate of Drug	Crime rate of Larceny				Crime rate of violence			
		Burglary	Automobile Theft	Motorcycle Theft	Total Larceny	Robbery	Abrupt Taking	Forcible Rape	Total Violent
Temperature	0.0129***	-0.0021***	-0.0050***	-0.0034***	-0.0106***	0.0002**	0.0016***	-2.60e-05	0.0018***
	(0.0007)	(0.0004)	(0.0008)	(0.0003)	(0.0008)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
One Lagged Period	-0.0025**	0.0017***	0.0054***	0.0012***	0.0083***	-0.0001	-0.0004**	9.61e-05	-0.0004*
	(0.0010)	(0.0004)	(0.0006)	(0.0003)	(0.0008)	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Two Lagged Period	-0.0022**	0.0007	0.0004	-0.0001	0.0010	-0.0001	-0.0005***	3.18e-05	-0.0005**
	(0.0009)	(0.0004)	(0.0007)	(0.0003)	(0.0010)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Three Lagged Period	-0.0019***	0.0009*	0.0012	0.0002	0.0023**	0.0001	-0.0003**	2.95e-05	-0.0002
	(0.0005)	(0.0005)	(0.0007)	(0.0003)	(0.0010)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Precipitation	-0.0006***	-8.31e-05	-0.0003***	-6.45e-05	-0.0005***	-9.19e-06	-4.18e-05**	-2.89e-06	-5.39e-05**
	(0.0001)	(4.94e-05)	(0.0001)	(0.0001)	(0.0001)	(6.13e-06)	(1.36e-05)	(9.15e-06)	(0.0001)
One Lagged Period	1.41e-05	0.0002***	-0.0001	-1.96e-06	8.08e-05	-8.01e-06	-7.42e-06	-7.47e-06	-2.29e-05
	(6.44e-05)	(4.02e-05)	(0.0001)	(4.52e-05)	(0.0001)	(7.64e-06)	(1.18e-05)	(7.44e-06)	(0.00002)
Two Lagged Period	-0.0001	-7.51e-05	0.0001	1.78e-05	8.47e-07	-6.34e-06	-1.54e-05**	2.56e-06	-1.91e-05
	(7.26e-05)	(4.70e-05)	(0.0001)	(3.77e-05)	(0.0001)	(5.13e-06)	(6.53e-06)	(1.36e-05)	(0.00002)
Three Lagged Period	-0.0001	6.07e-05	-0.0001	4.85e-05	7.04e-06	4.49e-06	3.07e-06	1.68e-05	2.44e-05
	(9.14e-05)	(4.31e-05)	(0.0001)	(2.99e-05)	(0.0001)	(1.29e-05)	(2.70e-05)	(1.59e-05)	(4.66e-05)
Medium	-0.1096**	-0.0139	0.0739	0.0361*	0.0962	-0.0028	-0.0070	-0.0012	-0.0110
	(0.0372)	(0.0241)	(0.0561)	(0.0172)	(0.0588)	(0.0033)	(0.0047)	(0.0059)	(0.0076)
One Lagged Period	0.0233	0.0031	0.0780	-0.0296	0.0516	0.0024	0.0193*	0.0026	0.0243*
	(0.0416)	(0.0245)	(0.0668)	(0.0257)	(0.0718)	(0.0039)	(0.0098)	(0.0071)	(0.0133)
Two Lagged Period	-0.0965	0.0208	0.0354	0.0174	0.0736	0.0009	-0.0063	0.0024	-0.0029
	(0.0642)	(0.0374)	(0.4890)	(0.0229)	(0.0696)	(0.0048)	(0.0092)	(0.0063)	(0.0129)
Three Lagged Period	0.0680	-0.0387	-0.1729***	0.0082	-0.2034***	0.0056	-0.0026	-0.0068	-0.0038
	(0.0657)	(0.0385)	(0.4090)	0.0124	(0.0557)	(0.0044)	(0.0054)	(0.0081)	(0.0088)
Strong	-0.1289**	-0.0741	0.0156	0.0485	-0.0100	0.0028	-0.0098	-0.0011	-0.0081
	(0.0433)	(0.0462)	(0.0591)	(0.0279)	(0.0824)	(0.0063)	(0.0077)	(0.0079)	(0.0161)
One Lagged Period	0.0830	0.0161	0.0156	0.0126	0.0443	-0.0037	0.0026	0.0057	0.0246
	(0.0605)	(0.0341)	(0.0766)	(0.0293)	(0.1005)	(0.0078)	(0.0134)	(0.0094)	(0.0204)

Two Lagged Period	-0.2081**	0.0341	0.1015*	0.0013	0.1369	0.0129	-0.0110	0.0057	0.0076
	(0.0770)	(0.0448)	(0.0515)	(0.0268)	(0.0883)	(0.0085)	(0.0124)	(0.0103)	(0.0188)
Three Lagged Period	0.1551*	-0.6137	-0.1364**	0.0613***	-0.1365*	0.0005	0.0032	-0.0078	-0.0041
	(0.0723)	(0.0426)	(0.0480)	(0.0160)	(0.0730)	(0.0067)	(0.0081)	(0.0093)	(0.0138)
Warning Frequency	-0.0016	-0.0038**	0.0024	0.0006	-0.0008	-0.0001	0.0001	9.94e-05	0.0001
	(0.0016)	(0.0013)	(0.0025)	(0.0006)	(0.0032)	(0.0002)	(0.0002)	(0.0002)	(0.0004)
One Lagged Period	0.0014	0.0020	0.0004	0.0010	0.0034	0.0002	4.70e-05	-0.0003	-0.0001
	(0.0023)	(0.0012)	(0.0036)	(0.0006)	(0.0038)	(0.0002)	(0.0004)	(0.0002)	(0.0004)
Two Lagged Period	-0.0025	-0.0006	-0.0002	-0.0013	-0.0022	-0.0003	-0.0001	0.0004	0.00004
	(0.0029)	(0.0013)	(0.0022)	0.0010	(0.0024)	(0.0002)	(0.0003)	(0.0004)	(0.0003)
Three Lagged Period	0.0009	-0.0006	-0.0013	0.0015*	-0.0005	0.0002	0.0001	2.46e-05	0.0003
	(0.0023)	(0.0009)	(0.0020)	(0.0007)	(0.0023)	(0.0003)	(0.0002)	(0.0004)	(0.0004)
Maximum Wind Speed	0.0022**	0.0022	-0.0023	-0.0008	-0.0009	0.0001	9.37e-05	-0.0002	-2.08e-07
	(0.0010)	(0.0013)	(0.0018)	(0.0005)	(0.0024)	(0.0001)	(0.0002)	(0.0002)	(0.0003)
One Lagged Period	-0.0017	-0.0011	-0.0012	-0.0005	-0.0028	-0.0001	-0.0004	0.0003	-0.0002
	(0.0016)	(0.0010)	(0.0023)	(0.0006)	(0.0027)	(0.0002)	(0.0002)	(0.0002)	(0.0003)
Two Lagged Period	0.0035	-0.0002	-0.0022	0.0002	-0.0022	-4.09e-05	0.0003	-0.0003	-5.62e-05
	(0.0021)	(0.0008)	(0.0017)	(0.0007)	(0.0017)	(0.0002)	(0.0003)	(0.0002)	(0.0003)
Three Lagged Period	-0.0024	0.0012	0.0056***	-0.0008*	0.0060***	-3.31e-05	-0.0001	0.0001	-9.41e-05
	(0.0018)	(0.0008)	(0.0007)	(0.0004)	(0.0012)	(0.0002)	(0.0002)	(0.0003)	(0.0003)
Landfall	0.0709**	0.0537*	0.0643	-0.0077	0.1103**	-0.0014	-0.0025	0.0065	0.0026
	(0.0260)	(0.0256)	(0.0428)	(0.0118)	(0.0466)	(0.0033)	(0.0041)	(0.0051)	(0.0090)
One Lagged Period	0.0311	-0.0231	-0.0449	-0.0112	-0.0793	-0.0005	-0.0068	-0.0052	-0.0124
	(0.0398)	(0.0229)	(0.0500)	(0.0143)	(0.0545)	(0.0039)	(0.0072)	(0.0053)	(0.0085)
Two Lagged Period	0.0295	0.0284	0.0556	0.0106	0.0946	0.0049	-0.0022	-0.0004	0.0023
	(0.03586)	(0.0401)	(0.0434)	(0.0159)	(0.0669)	(0.0070)	(0.0077)	(0.0057)	(0.0118)
Three Lagged Period	0.0458*	-0.0031	0.0306	-0.0138	0.0136	-0.0055	0.0060	0.0018	0.0023
	(0.0229)	(0.0272)	(0.0420)	(0.0145)	(0.0658)	(0.0052)	(0.0062)	(0.0052)	(0.0098)
Time	-0.0002***	-0.0001***	2.29e-05***	-3.45e-05***	-0.0001***	-6.76e-06***	1.60e-05***	-2.92e-06***	-2.57e-05***
	(1.75e-06)	(1.50e-06)	(1.84e-06)	(6.72e-07)	(1.63e-06)	(2.54e-07)	(4.34e-07)	(2.59e-07)	(6.24e-07)
Constant	0.5923***	0.3812***	0.3744***	0.2258***	0.9813***	0.0224***	0.0389***	0.0164***	0.0777***
	(0.0087)	(0.0053)	(0.0120)	(0.0039)	(0.0145)	(0.0019)	(0.0020)	(0.0019)	(0.0040)

Note: The values in the parenthesis are robust standard errors. * $p<0.1$, ** $p<0.05$ and *** $p<0.01$.

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