Beware of Dog: Impact of Air Pollution on Dog Bites

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As air pollution has been shown to affect the physical health of both human and animal, the natural question is whether air pollution has the same effects on the aggressive behavior of dogs as it has on humans. In this paper, I estimate the effect of air pollution on dog bite incidence by employing a Poisson pseudo-maximum likelihood (PPML) method on the dog bites data from seven US cities: New York, Dallas, Baltimore, Houston, Louisville, Chicago and Baton Rouge. To mitigate the possible endogeneity problem, I also use wind direction as an instrument for air pollution. Air pollution is found not to have a statistically significant effect on dog bites, animal bites, and animal aggression. However, weather conditions, especially maximum temperature, are identified as significant factors, showing a positive association with the number of dog bites.

I. Introduction

Air pollution has been linked with aggressive behavior of human beings. However, whether the same pollution-aggressive relationship holds for the man's best friend is a question rarely investigated. In this paper, I explore the possible association between air pollution and the prevalence of dog bites.

According to American Pet Products Association, "65.1 million U.S. households own a dog". The average count of dog bites in the US is 1.1 per 1,000 population with an average dog bites-related emergency department (ED) visits of 337,103 from 2005 to 2013 where medical costs are estimated to be 400 million US dollars per year. ((Loder, 2019)) Each day around 1000 people receive treatments at emergency department for dog-related non-fatal injuries with 349,961 ED visits in 2018 alone. ((Tuckel and Milczarski, 2020)) In the year 2020, 47,454 patients had to go through reconstructive procedures due to dog bites repair. ((American Society of Plastic Surgeons, 2020)) The liability claims due to dog bites and injuries cost the homeowners 1,136 million US dollars in 2022.((Insurance Information Institute, 2020)) It is clear from these statistics that dog bites cause a signif-

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icant welfare loss to human beings in the form of medical and insurance claims, physical and mental sufferings. These losses to human welfare show the importance of the research topic and justify the undertaking of this research project.

The main research question in this paper is: is there any association between air pollution and the number of dog bite incidences?

The research question of this study has many policy implications. First, most of the cost-benefit analyses of air pollution do not include costs (medical and liability insurance) of dog bites possibly caused by air pollution. This undervalues the costs/benefits, and the evaluation basis of pollution reduction program becomes faulty. Second, this estimation (and possibly valuation) of dog bites due to pollution can potentially add pollution aspect into the decision equation of policymakers while enacting dog bites law, specially "strict liability" laws in the polluted states. My contribution to the literature is that this study is one of the first few papers and the first paper in environmental/health economics to investigate the association between air pollution and the prevalence of dog bites. Secondly, this is the first paper to provide a clear causal identification strategy to investigate the impact of air pollution on the counts of dog bite.

II. Related literature

Air pollution has been found to affect the aggressive behaviors in human beings, mostly manifested in committing crimes. ((Burkhardt et al., 2019)) investigate the effects of short-term exposure to air pollution on aggressive behavior of human being at a national scale and find that a 10% increase in same-day exposure to PM2.5 is associated with a 0.14% increase in violent crimes, nearly all of which is driven by increases in assaults, which are indicative of aggressive behavior. Similarly, they find that a 10% increase in same-day exposure to ozone is associated with a 0.3% increase in violent crime or a 0.35% increase in assaults. Using wind direction as an instrument, ((Herrnstadt et al., 2021)) find that air pollution increases violent crime but not property crime, consistent with research from biology and medicine linking air pollution and aggression. Using quasi-experiment of the NOx Budget Trading Program, Chen and Li ((2020)) find that the program significantly reduced violent and property crimes in participating states by roughly 3.7% and 2.9%, respectively.

Using a zero-inflated Poisson generalized additive (ZIGAM) model, ((Dey, Zanobetti and Linnman, 2023)) estimated the possible relationship between daily counts of dog bites and air pollution in the form of daily average of PM2.5 and daily 8-hour maximum ozone -both obtained from Environmental Protection Agency's Air Quality System monitors. Apart from the air pollution measurements, they also included UV irradiation, precipitation and maximum daily temperatures. Though they find statistically significant positive effects of ozone, temperature, UV irradiation and precipitation, they find no significant effects of PM2.5 on dog bite incidences.

Apart from human beings, monkeys are another animal that shows higher levels of social conflicts upon exposure to a higher level of air pollution. For this study, ((Xu et al., 2021)) video-recorded 90 monkey of Hongshan Zoo in northern China from March 2017 to February 2018 and analyzed the impact of AQI using linear regression model, one day lag linear regression and partial eta squared. In addition to the effects of pollution, they find that temperature has a non-linear relationship with the conflicts among monkeys; monkeys fight less below 15 degrees Celsius and more than 35 degrees Celsius with a peak between 15 and 29 degrees Celsius.

Analyzing dog bites data in Florida, ((Matthias et al., 2014)) find that gender and age play significant roles in the dog bite incidents as females have a higher possibility of getting bitten by dogs than males and boys are more likely to be bitten by dogs than girls. Moreover, persons aged more than 6 years have more than three times chances of being bitten by unfamiliar dogs. A relatively well researched topic and question in public health is the dog-child interaction and why children are bitten by dogs, respectively.

Though there is no peer-reviewed paper showing the association between air pollution and dog bites, the first paper to investigate the relationship between temperature and counts of dog bite is ((Zhang et al., 2017)). Employing a quasi-Poisson regression with distributed lag non-linear model on data of emergency room visits due to dog bites in Beijing, China, they find that temperature has a U-shaped relationship with dog bites as risk of dog bites increases with higher and lower temperature with higher risk, immediate and longer effect on the hot days. Moreover, stratified analysis of this u-shaped relationship shows variations by gender and age groups as females have a higher risk of getting bitten by dogs on cold temperatures comparing to males who have a higher dog bites risk on hot days and temperature does not affect the dog bites for the age group of 15 to 21. Though they didn't show how air pollution affects counts of dog bite, the sensitivity analysis shows the relationship between temperature and dog bites remain unchanged even after adjusting for air pollutants like PM2.5, SO2, CO and NO2.

A possible pathway for air pollution to affect dog bites can be through stress. Conducting a meta-analysis of 33 studies on the effects of pollution on the level of oxidative stress in the wild terrestrial animals, ((Isaksson, 2010)) have found that a higher level of pollution leads to the higher level of oxidative stress- a phenomenon due to the imbalances between free radicals and antioxidants. Breed of the dogs is also found to be important as Pitbull accounted 42 percent of all dog bites-related fatalities in the US from 1979 to 1988. ((Overall and Love, 2001)) Moreover, dog bites injuries by this breed also happened to be the most severe. ((Patronek et al., 2013)) identified the owner's failure to neuter dogs as one of the main preventable factors of deaths due to dog bites by analyzing 256 dog bite–related fatalities (DBRFs) in the US from 2000 to 2009, However, breed is not found as a preventable factors of dog bites-related deaths.

III. Data

For this paper, I incorporate five different types of data in the final dataset: dog bites data, air pollution data, weather data, census data and GIS data. The data sources and important key variables are discussed as follows:

A. Dog bites data:

For dog bites data, I extract data from seven different cities: New York City (NYC) of New York, Dallas (Texas), Houston (Texas), Baton Rouge (Louisiana), Baltimore (Maryland), Louisville (Kentucky), and Chicago (Illinois). The data sources, sample sizes and periods and information on key variables are as follows: I have obtained the dog bites data of New York City (NYC) from the NYC Open Data portal and the data is prepared by the New York City Department of Health and Mental Hygiene (NYC DOHMH). This dataset includes the dog bite identifier, location and date-time of the bite, age, gender and breed of dog and the information of whether the dog is spayed or neutered. One limitation of this dataset is- no victim information (like age or gender) is provided and the sample period runs from 2015 to 2021. I have extracted the dog bites data of Dallas (Texas) from publicly available Dallas Animal Services data for the year 2016 to 2023. This dataset includes unique bite numbers, bite date and location, victim age and relationship to the dog, bite severity and circumstances etc. I have obtained the dog bites data of Baton Rouge (Louisiana) from Baton Rouge Animal Control and Rescue Center (ACRC)'s Animal Control Incidents data available publicly at Baton Rouge Open Data for the year 2012 to 2023. Dog bites data for the city of Chicago is not publicly available; I submitted a Freedom of Information Act (FOIA) request to the Animal Care and Control department of Chicago. The other cities, years of sample, key variables and sources of data are provided in Table 1.

Cities	Years	Key variables	Sources
Baltimore	2017-2021	Latitude and longitude, Incident Date (Note: Animal Bites Only, Not Specific Dog Bites)	Baltimore City 311 Services
Baton Rouge	2012-2023	Incident date, dog breed, sex, zip code	Baton Rouge Animal Control and Rescue Center
Dallas	2016-2023	Incident date, Zip code, Bite Type	Dallas Animal Services
Houston	2012-2016	Incident Date, Latitude and longitude (Note: Animal Bites Only, Not Specific Dog Bites)	BARC Animal Service Requests
Louisville	2012-2023	Dog breed, Sex, Color, Zip code	Louisville Metro Open Data
New York	2015-2021	Dog Breed, Age, Gender, SpayNeuter status, Zip Code	New York City Department of Health and Mental Hygiene
Chicago	2019-2020	Latitude and longitude, Incident Date	Animal Care and Control Department of Chicago

Table 1—City and Year Availability of Dog Bite Data for Analysis (2012-2023)

Note: In this table, I provide information on the availability of dog bite data by city and year. The sample used in the main specifications includes data ranging from 2012 to 2023. The first column lists the cities that contributed dog bite data for my analysis. The second column indicates the respective years for which dog bite data is available. Furthermore, the third column highlights key variables within the data set. The last column provides sources or any relevant notes pertaining to the data, if applicable.

B. *Air pollution data:*

I extract the air pollution data from the Atmospheric Composition Analysis Group of Washington University in St. Louis This surface PM2.5 data includes monthly mean, minimum and maximum PM 2.5 for all the cities during the period of available dog bites data.

C. *Weather data:*

I obtain the weather data from Visual Crossing for the cities of Baton Rouge, Louisville, Houston, Baltimore, New York City, Dallas, and Chicago which are available from 2000 to 2023. This data includes daily measurements of meteorological data, encompassing temperature (°C), wind speed (m/s), wind direction (°), humidity (gram per cubic metre) and relative precipitation (in millimeters).

D. Census data:

I use the Zip code data from the 2020 TIGER/Line Shapefiles of the U.S. Census Bureau. This dataset provides the population, income, and other important census information about the dog bites area. GIS data of primary and secondary roads TIGER/Line shapefile is extracted from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database.

IV. Empirical strategy

As the number of dog bites is a count, a regular OLS fixed effect model will give inconsistent estimates.((Silva and Tenreyro, 2006)). I estimate the following regression model for each of the four cities separately via Poisson pseudo-maximum likelihood (PPML) to identify the effect of air pollution on dog bites:

$$Bites_{z,t} = \beta_1 Pollutants_{z,t} + W^{'}_{z,t}\beta_2 + \rho_i + \phi(t) + \epsilon_{z,t} \tag{1}$$

Here,

- $Bites_{z,t}$: the number of monthly (t) dog bites per Zip code area z
- $Pollutants_{z,t}$: concentration of pollutants of Zip code area z in period t
- $W^{'}_{z,t}$: a vector of weather control variables including monthly maximum temperature, minimum temperature, humidity, dew and precipitation
- ρ_z : Zip code area fixed effects
- $\phi(t)$: time fixed effect
- $\epsilon_{z,t}$: idiosyncratic error. Standard errors are clustered at the Zip code area

Here β_1 is the coefficient of interest which shows the marginal effect of air quality on the dog bites. Following ((Burkhardt et al., 2019)), I use the restricted cubic splines of monthly maximum temperature, monthly minimum temperature, and monthly precipitation. Moreover, as a sensitivity analysis, I also use bin indicators to model the distribution of temperatures and precipitations as used in ((Chen and Li, 2020)). One of the benefits of using PPML is that there is no need to specify a distribution for the dependent variable. Moreover, it provides consistent estimation in the presence of heteroskedasticity.((Correia, Guimarães and Zylkin, 2020)) ((Silva and Tenreyro, 2006))

The justification of using Zip code as the geographical unit is the fact of territorial nature of stray dogs. Moreover, while analyzing the dog-victim relationship, ((Overall and Love, 2001)) find that most of the dog bite incidences were inflicted by pet dogs, not by stray dogs. Then the assumption is the pet dogs are in the same area as the bite location.

The key identifying assumption for capturing a causal relationship between air pollution and counts of dog bites estimated by equation (1) is that unobserved determinants of dog or the victim are uncorrelated with the level of pollution. With the time and Zip code fixed effects to absorb the unobserved variation in the characteristics of dogs and humans along with the controls for temperature and precipitation, this assumption will be less likely to be violated. However, it is hard to test whether any other factors are correlated with both air pollution and dog bites. This is a naive regression of the this study as there still remains a possibility of endogeneity issue (omitted variable bias or self-selection bias etc.). To mitigate potential sources of omitted variable bias and measurement error, this study leverages fluctuations in the monthly average PM2.5 concentration within Zip codes, attributable to variations in monthly average wind direction ((Deryugina et al., 2019; Bondy, Roth and Sager, 2020)). This approach enables the estimation of PM2.5's impact on dog bite incidents without the need to identify specific pollution sources or grasp the nuanced geographic features of the study area. Furthermore, it affords a wide-ranging geographical scope and a lengthy temporal perspective, aligning with the research design's requirements. More specifically I estimate the following equation as Bondy, Roth and Sager ((2020)):

$$PM2.5_{z,t} = \theta_z WindDir_{z,t} + W^{'}_{z,t}\lambda + V^{'}_{z,t}\eta + D^{'}_{z,t}\zeta + \rho_z + \phi(t) + \nu_{z,t} \tag{2}$$

$$Bites_{z,t} = exp\{\beta_1 WindDir_{z,t} + W^{'}_{z,t}\beta_2 + V^{'}_{z,t}\beta_3 + D^{'}_{z,t}\beta_4 + \psi_z + \sigma(t) + \mu_{z,t} + \}\epsilon_{z,t} \tag{3}$$

Here,

- $Bites_{z,t}$: the dog bite incidence at Zip code z in month t
- $WindDir_{z,t}$: serves as the instrumental variable for PM2.5, categorizing wind direction into three quadrants: o°– 90°, 91°– 180°, and 181°– 270°, with the fourth quadrant acting as the reference or baseline wind direction.

- $W'_{z,t}$: a vector of weather control variables including monthly maximum temperature, minimum temperature, wind speed, and precipitation
- $V'_{z,t}$: a victim characteristics vector like age and gender
- $D'_{z,t}$: a dog characteristics vector like breed, age, sex etc.
- ρ_z or ψ_z : Zip code fixed effects
- $\phi(t)$ or σ_t : time fixed effect
- $\epsilon_{z,t}$: idiosyncratic error term

Similar to Deryugina et al. ((2019)), the identifying assumption at the core of the instrumental variables approach is as follows: after thorough adjustment for a range of fixed effects (encompassing factors like Zip code, month-year combinations, and city-month variations) as well as meteorological variables (comprising maximum and minimum temperatures, precipitation, wind speed, and their interplay), any alterations in a Zip code's monthly wind direction remain unrelated to changes in dog bite incidents, except through their influence on air pollution.

V. Results

The results presented in Table 2 clarify the impact of air pollution, as measured by surface-level monthly mean, minimum, and maximum PM2.5 concentrations, on occurrences of dog bites, other animal bites, and instances of animal aggression. The analysis employs the baseline Poisson pseudo-maximum likelihood (PPML) model outlined in Equation 1, with the resulting coefficient β_1 shown in Table 2. In Columns 1 through 6, I include weather controls, involving quartile bins of maximum and minimum temperature, wind speed, humidity, precipitation, and dew. Beyond these quartile bins, an alternative estimation is conducted using a restricted cubic spline for these weather parameters, revealing minimal deviation from the quartile bins approach.

Furthermore, Columns 1 to 3 incorporate fixed effects for Zip Code and month of the year, effectively mitigating time-varying differences across different zip codes. Expanding upon this, Columns 4 to 6 include additional city fixed effects, which serve to account for variations specific to each city within the respective Zip code. However, all coefficients exhibit statistical insignificance at the conventional significance levels of 1%, 5%, and even 10%. The signs and magnitudes of the coefficients vary based on the combination of fixed effects, the variable of interest, and the dependent variable; nevertheless, none of them achieve statistical significance.

Given the extensive literature highlighting the significant impact of weather conditions on the aggressive behavior of dogs, humans, and other animals, I extend the analysis by estimating Equation 1 with quartile bins representing various weather conditions. In Table 3, columns (1) and (2) reveal that, on average, both maximum and minimum temperatures contribute to an increase in the incidence of dog and other animal bites. The statistically significant magnitude can be as high as 0.871, signifying that a 1-degree increase in the first quartile of maximum temperature leads to a substantial 138.930% surge in animal bites. Importantly, it is noteworthy that the third quartile of maximum or minimum temperature does not result in a significant increase in either dog or other animal bites, rejecting the notion of a U-shaped relationship with temperature as found in prior research ((Zhang et al., 2017)). Furthermore, Columns (3) exhibit no significant changes in other animal aggressions, displaying mixed signs.

Table 4 presents the coefficients detailing the effects of wind speed, humidity, precipitation, and dew on the incidence of dog bites, animal bites, and cases of animal aggression. Most of these coefficients exhibit statistical insignificance with relatively smaller magnitudes, except for precipitation and dew, which show positive and negative effects on dog bites, respectively.

In an effort to address potential confounding factors, wind direction is employed as an instrument for air pollution. The estimation results, as detailed in Table 5 using equations 2 and 3, mirror the baseline findings, revealing no significant impact of air pollution, instrumented by wind direction, on the frequency of dog bites.

Given the non-significant effect of air pollution on dog bites, an alternative outcome variable is considered by using dog bites per 1000 people. Upon re-estimating equations 2 and 3, consistent with the baseline results and the instrumental variable approach using the raw count of dog bites, no significant change is observed in the rate of dog bites per thousand people attributable to air pollution in Table 6.

	(1) Dog Bites	(2) Animal Bites	(3) Animal Aggression	(4) Dog Bites	(5) Animal Bites	(6) Animal Aggression
Monthly Mean PM2.5	-0.004	-0.029	0.005	-0.035	-0.062	0.008
	(0.014)	(0.026)	(0.021)	(0.022)	(0.042)	(0.043)
Monthly Minimum PM2.5	-0.018	-0.032	0.005	-0.057	-0.034	0.040
	(0.014)	(0.027)	(0.022)	(0.027)	(0.046)	(0.044)
Monthly Maximum PM2.5	-0.010	-0.037	-0.015	-0.040	-0.083	-0.017
	(0.013)	(0.025)	(0.017)	(0.026)	(0.045)	(0.028)
Controls	Y	Y	Y	Y	Y	Y
Zip Code FE	Y	Y	Y	Y	Y	Y
Month of the Year FE	Y	Y	Y	Y	Y	Y
City FE	N	N	N	Y	Y	Y
N	19329	7134	7072	18031	7134	6982

Table 2—Baseline Estimation Results

Note: In this table, I provide the results of the baseline model where I estimate the effect of air pollution on the number of dog bites, other animal bites and cases of animal aggression. The estimation method is Poisson pseudo-maximum likelihood (PPML) model specified in equation 1. Standard errors, clustered at the Zip code level, are provided in parentheses. Statistical significance levels are denoted as follows: *** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.10$.

	(1)	(2)	(3)
	Dog Bites	Animal Bites	Animal Aggression
1st Max Temp Quartile	0.230***	0.871***	-0.014
	(0.051)	(0.247)	(0.170)
2nd Max Temp Quartile	0.260***	0.666*	0.014
	(0.071)	(0.310)	(0.197)
3rd Max Temp Quartile	0.250**	0.648*	-0.064
	(0.094)	(0.326)	(0.196)
1st Min Temp Quartile	0.169***	0.028	0.105
	(0.049)	(0.216)	(0.101)
2nd Min Temp Quartile	0.160*	0.003	0.249
	(0.081)	(0.250)	(0.132)
3rd Min Temp Quartile	0.176	-0.115	0.104
	(0.096)	(0.286)	(0.144)
N	27760	7134	7072

Table 3—Results: Effects of Maximum and Minimum Temperature on the Number of Dog Bites, Animal Bites and Cases of Animal Aggression

Note: This table presents the the effect of maximum and minimum temperature on the number of dog bites, other animal bites and cases of animal aggression. The estimation method is Poisson pseudo-maximum likelihood (PPML) model specified in equation 1. Standard errors, clustered at the Zip code level, are provided in parentheses. Statistical significance levels are denoted as follows: *** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.10$.

	(1)	(2)	(3)
	Dog Bites	Animal Bites	Animal Aggression
1st Wind Speed Quartile	0.011	0.000	0.050
	(0.029)	(0.051)	(0.031)
2nd Wind Speed Quartile	0.013	0.013	0.068
	(0.036)	(0.075)	(0.052)
3rd Wind Speed Quartile	0.009	0.010	0.042
	(0.062)	(0.099)	(0.067)
1st Precipitation Quartile	0.000	-0.016	-0.003
	(0.038)	(0.045)	(0.029)
2nd Precipitation Quartile	0.073*	0.016	-0.027
	(0.035)	(0.048)	(0.036)
3rd Precipitation Quartile	0.082*	-0.006	0.026
	(0.040)	(0.065)	(0.046)
1st Humidity Quartile	-0.025	0.005	-0.017
	(0.028)	(0.110)	(0.072)
2nd Humidity Quartile	-0.028	0.054	-0.005
	(0.035)	(0.161)	(0.084)
3rd Humidity Quartile	-0.072	0.094	-0.051
	(0.056)	(0.165)	(0.096)
1st Dew Quartile	-0.193***	0.000	0.017
	(0.055)	(.)	(0.106)
2nd Dew Quartile	-0.162*	-0.275	-0.091
	(0.078)	(0.166)	(0.062)
3rd Dew Quartile	-0.184	-0.163	NA
	(0.102)	(0.193)	NA
N	27760	7134	7072

Table 4—Results: Effects of Wind Speed, Humidity, Precipitation and Dew on the Number of Dog Bites, Animal Bites and Cases of Animal Aggression

Note: This table presents the the effect of wind speed, humidity, precipitation, and dew on the number of dog bites, other animal bites and cases of animal aggression. The estimation method is Poisson pseudo-maximum likelihood (PPML) model specified in equation 1. Standard errors, clustered at the Zip code level, are provided in parentheses. Statistical significance levels are denoted as follows: *** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.10$.

	(1)	(2)	(3)
	Dog Bites	Animal Bites	Animal Aggression
Mean PM2.5	0.052	-0.082	-0.050
	(0.040)	(0.153)	(0.102)
Min PM2.5	0.025	-0.088	-0.016
	(0.034)	(0.138)	(0.090)
Max Pm2.5	0.021	-0.101	-0.009
	(0.039)	(0.155)	(0.100)
N	27760	7134	7072

Standard errors in parentheses

TABLE 5—RESULTS: EFFECTS OF AIR POLLUTION ON THE NUMBER OF DOG BITES, ANIMAL BITES AND CASES OF ANIMAL AGGRESSION WITH AN INSTRUMENTAL VARIABLE APPROACH

Note: This table presents the the effect of air pollution instrumented by wind direction on the number of dog bites, other animal bites and cases of animal aggression as specified in equations 2 and 3. Standard errors, clustered at the Zip code level, are provided in parentheses. Statistical significance levels are denoted as follows: *** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.10$.

	(1) Dog Bites Per 1,000 Population
Mean PM2.5	-0.018
	(0.110)
Min PM2.5	-0.013
	(0.094)
Max PM2.5	-0.014
	(0.108)
N	26199

TABLE 6—RESULTS: ALTERNATIVE OUTCOME VARIABLE

Note: This table presents the the effect of air pollution instrumented by wind direction on the number of dog bites per thousand people as specified in equations 2 and 3. Standard errors, clustered at the Zip code level, are provided in parentheses. Statistical significance levels are denoted as follows: *** for $p < 0.01$, ** for $p < 0.05$, * for $p < 0.10$.

VI. Conclusion and plans for future work

In this paper, I study the impact of air pollution on the counts of dog bite incidences in the US. For this research, I use dog bites data from seven different US cities and employ Poisson pseudo-maximum likelihood (PPML) estimation method and surface level PM 2.5 as a measurement of air pollution. Moreover, I also use the wind direction as an instrument for air pollution with the identification strategies like ((Deryugina et al., 2019)) or ((Anderson, 2020)). The study reveals that air pollution does not exhibit a statistically significant impact on occurrences of dog bites, animal bites, or animal aggression. Conversely, weather conditions, particularly maximum temperature, are identified as significant factors, demonstrating a positive correlation with the incidence of dog bites. My future steps include conducting a power analysis, heterogeneity analysis, getting crime data at the Zip code level, and testing "monotonicity" assumption of wind direction as an instrument for pollution. Moreover, if the estimated relationship between air pollution and dog bites for different cities with different empirical strategies showed contradictory results, I would need to explain the differences in results and justify the external validity of the research.

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Appendix: Figures

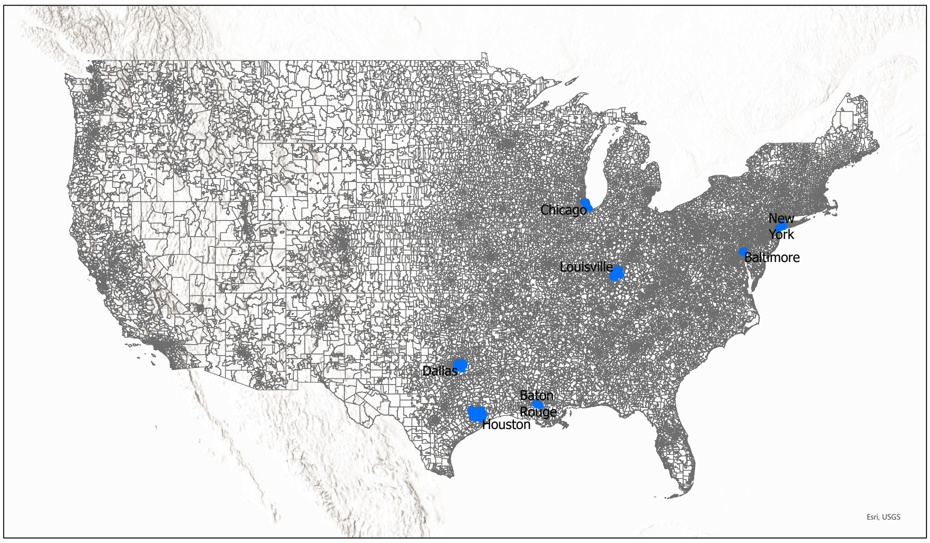

Figure A1. Study Area

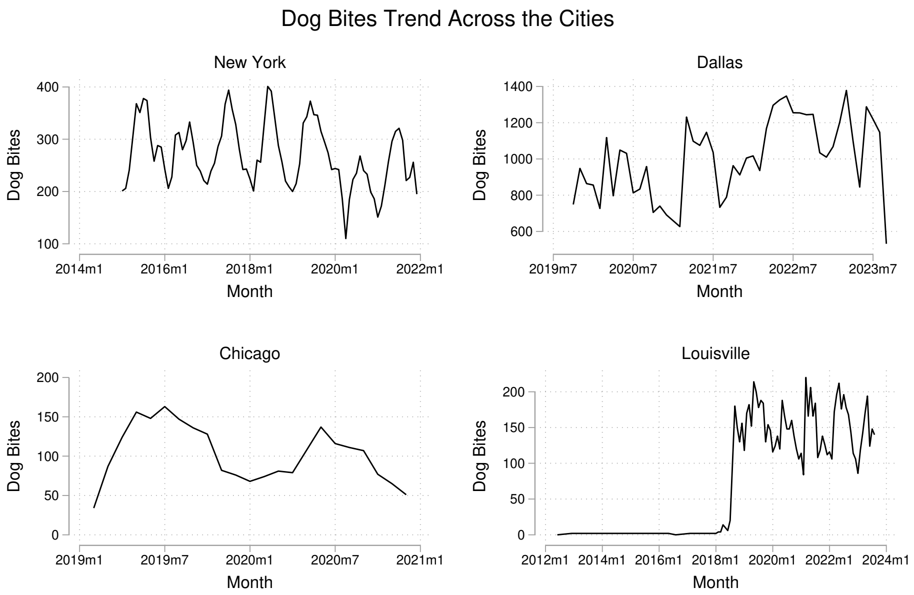

Figure A2. Dog Bites Trend Across U.S. Cities

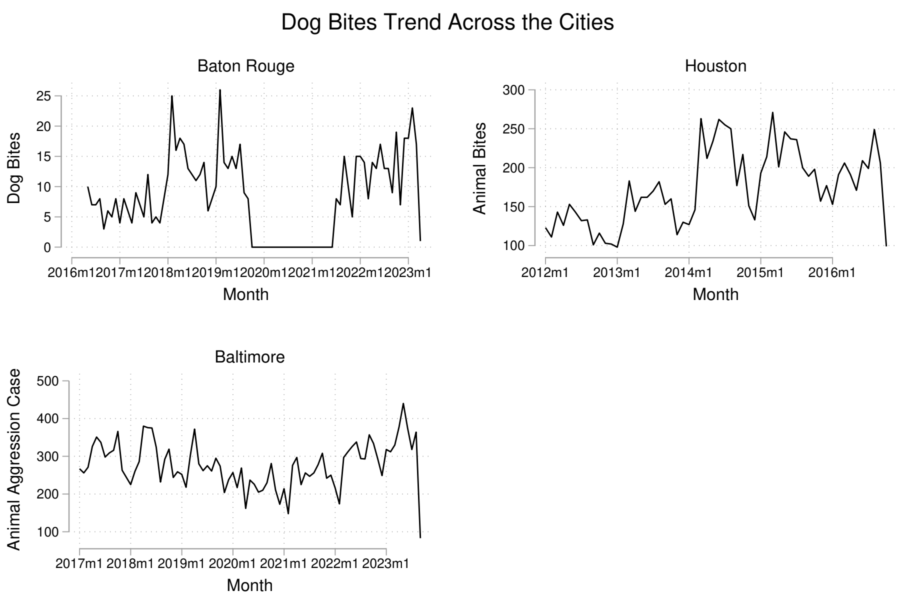

Figure A3. Dog Bites Trend Across U.S. Cities

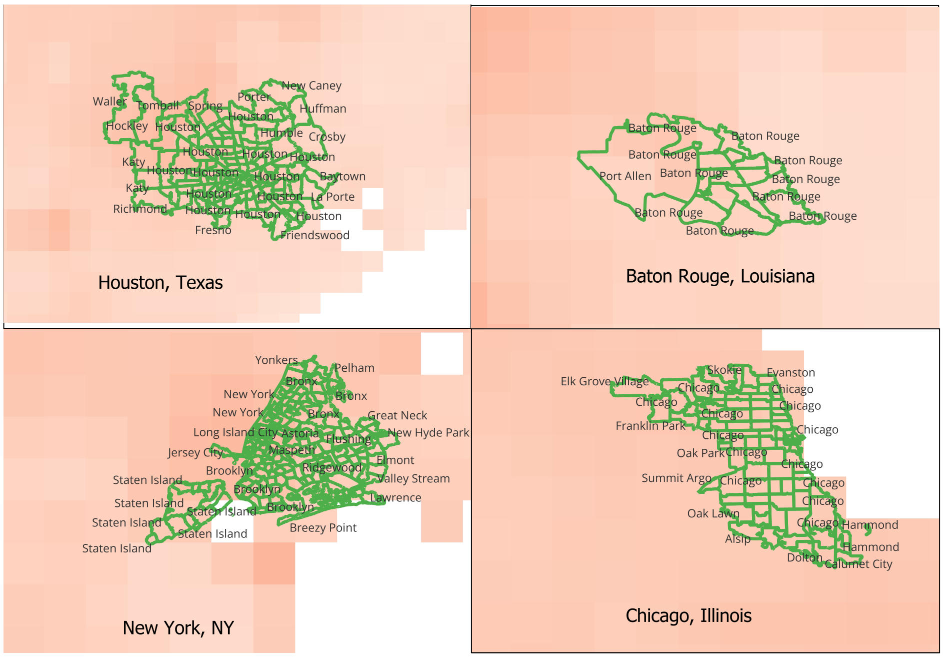

Figure A4. Surface PM2.5 for December 2016 Across U.S. Cities

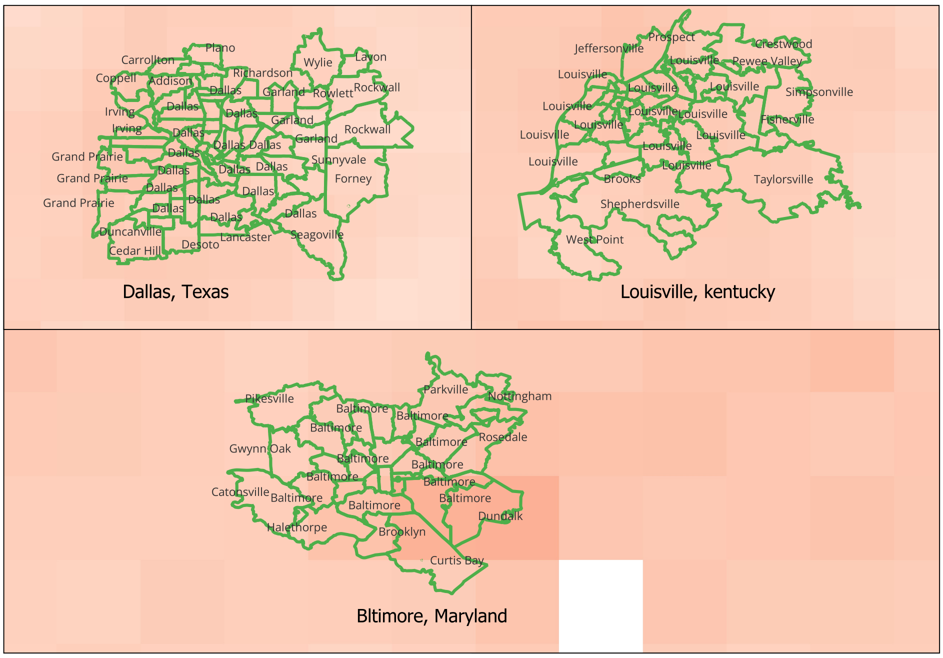

Figure A5. Surface PM2.5 for December 2016 Across U.S. Cities

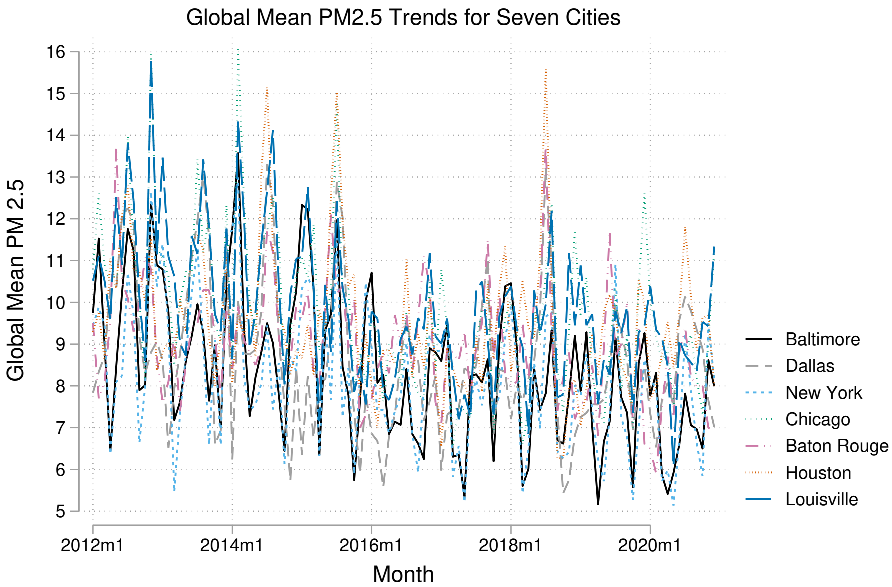

Figure A6. Monthly Mean Pollution Trends for All Seven Cities

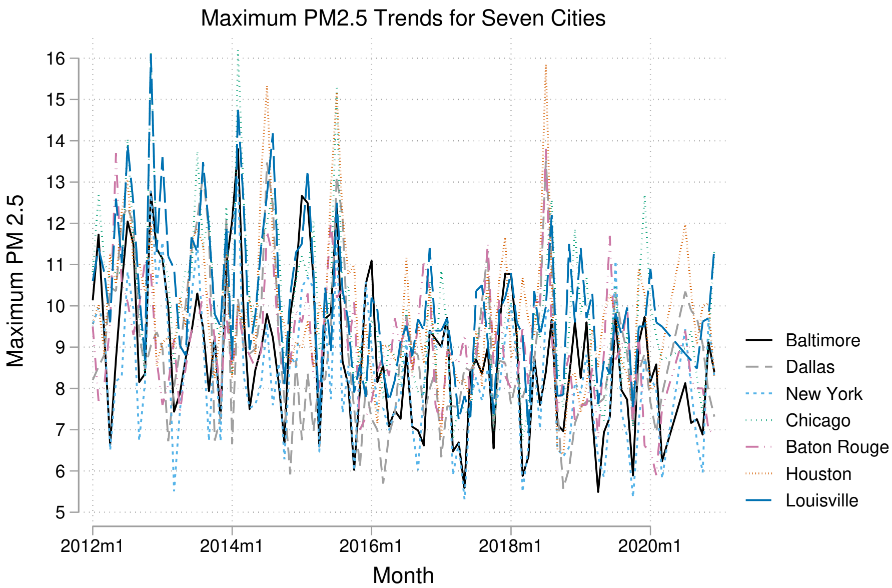

Figure A7. Monthly Maximum Pollution Trends for All Seven Cities

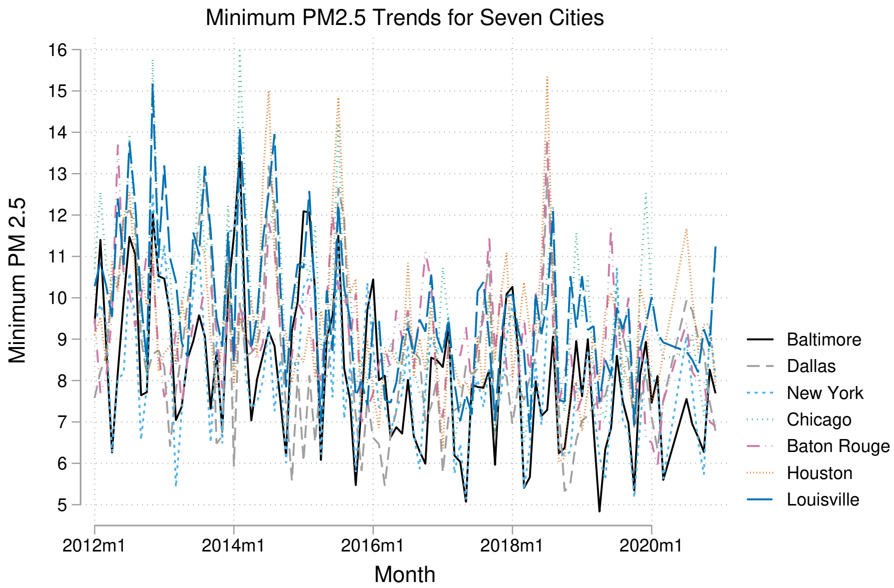

Figure A8. Monthly Minimum Pollution Trends for All Seven Cities

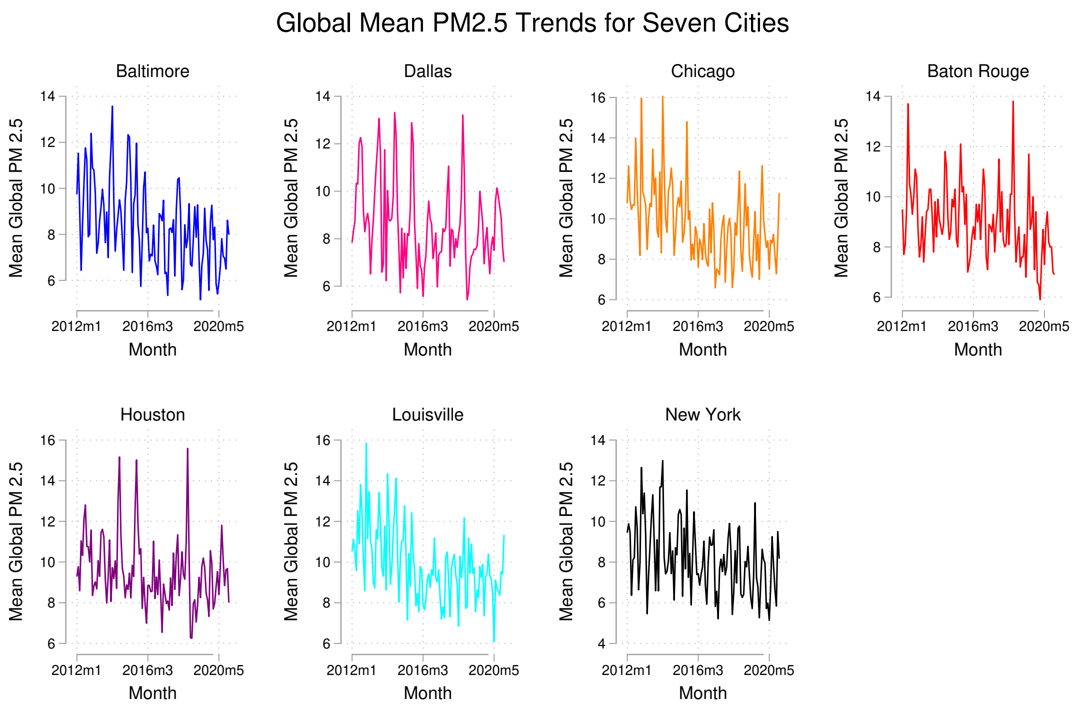

Figure A9. Monthly Mean Pollution Trends for All Seven Cities

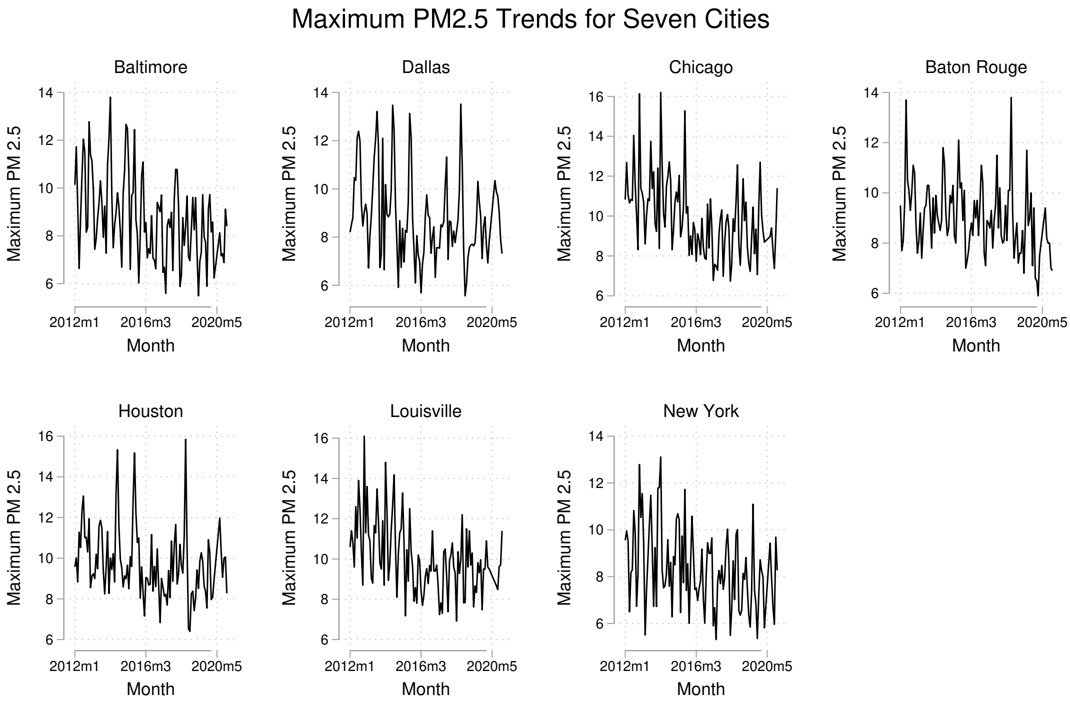

Figure A10. Monthly Maximum Pollution Trends for All Seven Cities

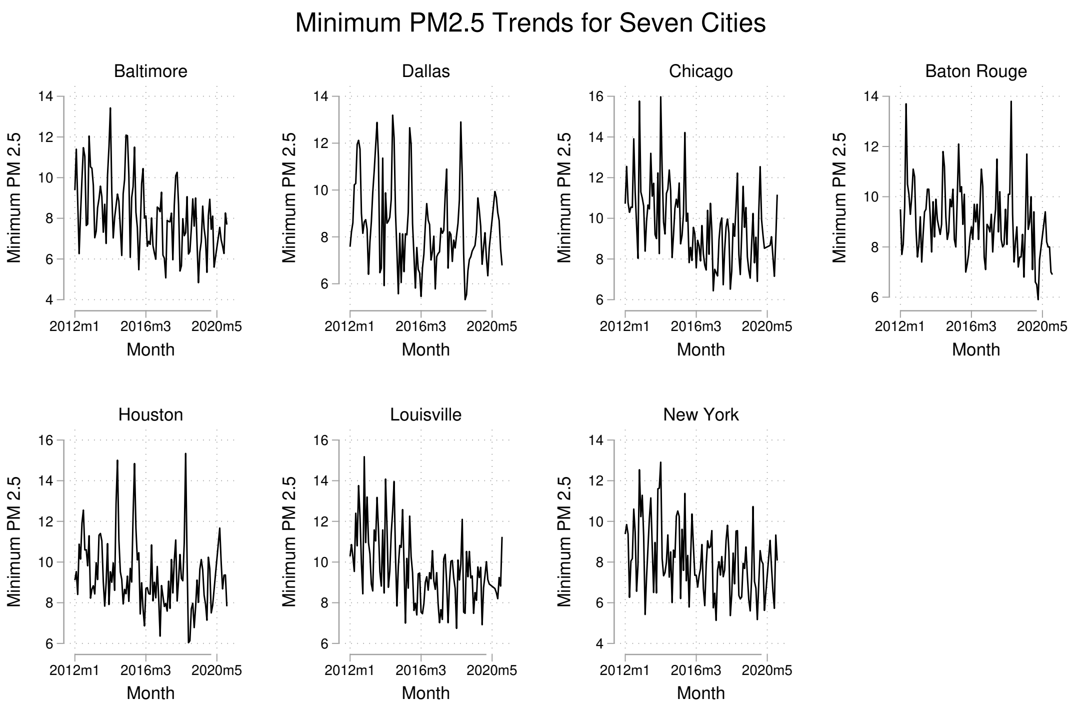

Figure A11. Monthly Minimum Pollution Trends for All Seven Cities

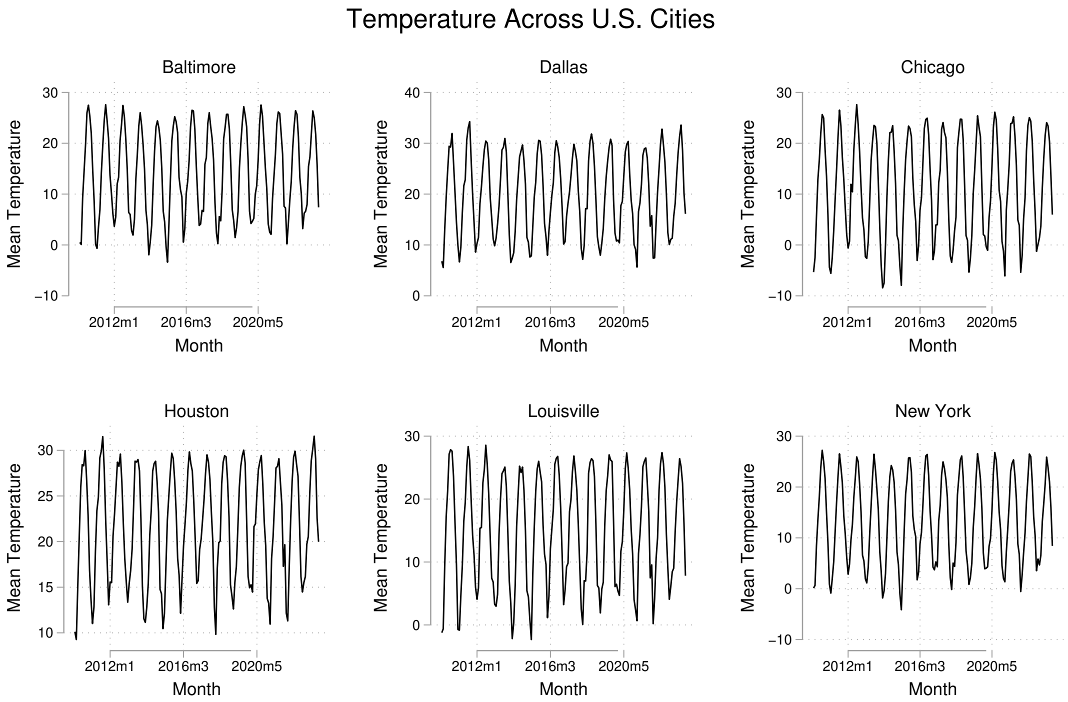

Figure A12. Temperature Across U.S. Cities

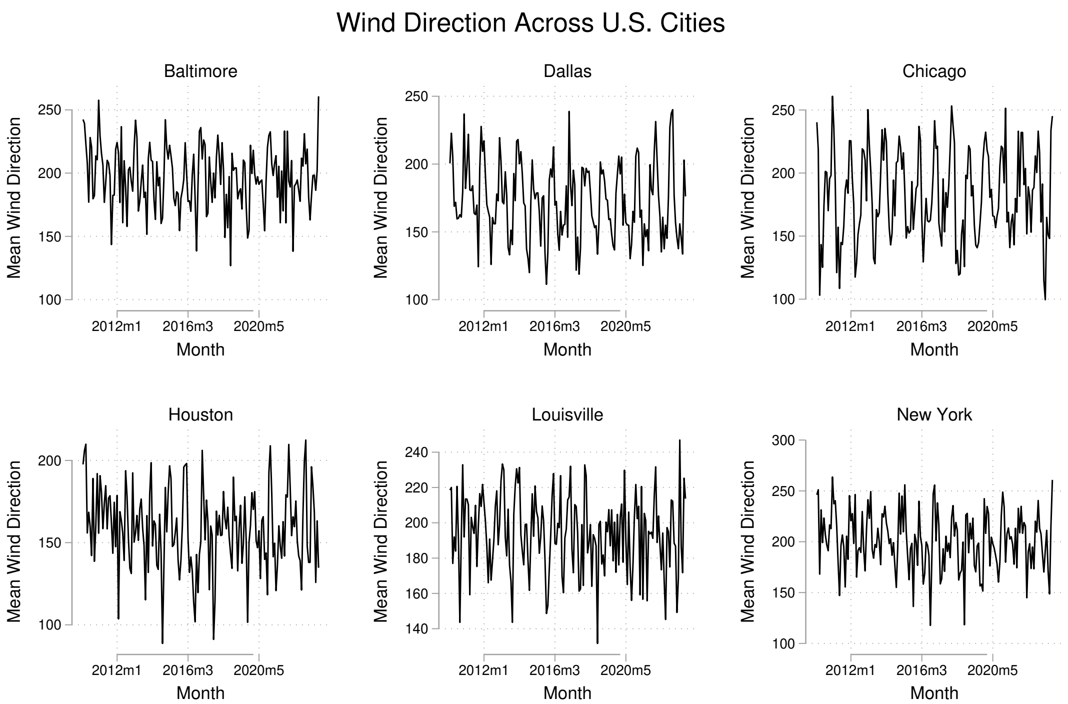

Figure A13. Wind Direction Across U.S. Cities

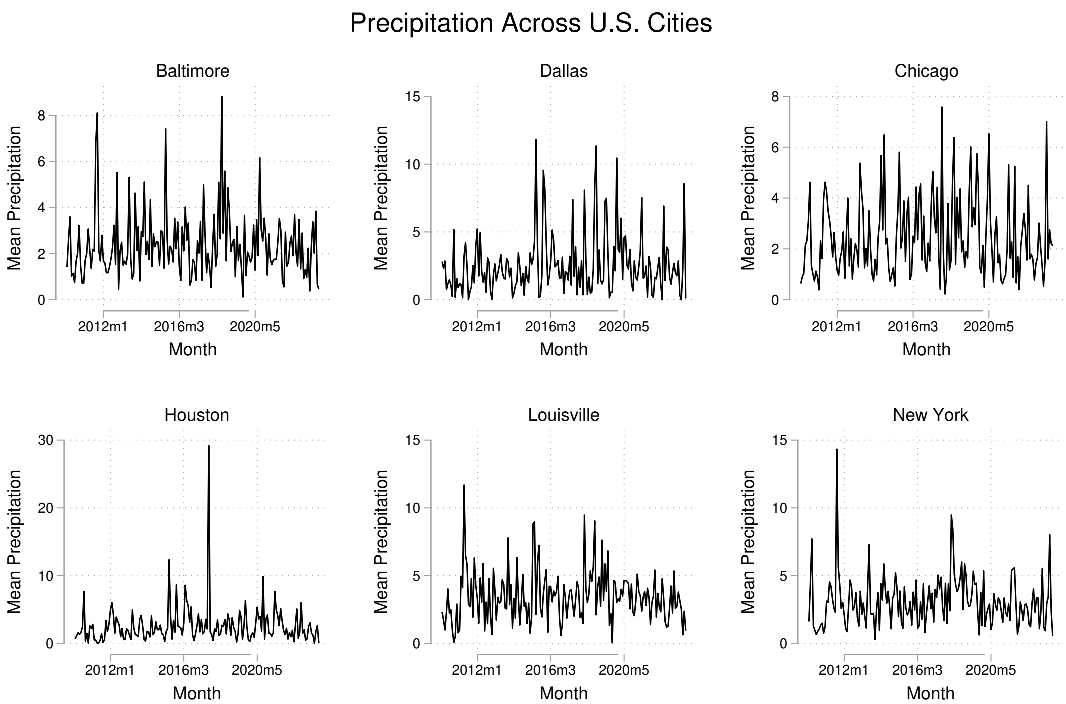

Figure A14. Precipitation Across U.S. Cities