Neglected Hazard: Mental Health and Roadway Noise

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Background

- When I was working on my dissertation, I lived near a busy road.
- How could anyone concentrate or get proper rest with that level of noise?
- More than 11 million people in the US live within 150 meters of a major highway.
- **RQ**: My study investigates whether roadway noise, which is ubiquitous in the US, is a factor contributing to mental health issues in the US.

Literature

- Poor mental health can lead to severe outcomes.
- Current driving factors: demographic and labor market influences; emerging evidence points to environmental stressors.
- Traffic noise at common urban levels can impact stress and sleep disturbances, both of which increase the risk of chronic conditions.
- We focus on roadway noise.
- Two challenges: the predominant focus on air pollution; the difficulty of linking precise roadway noise measurement to individual-level mental health outcomes.

This Study

- Combine the first-ever national noise map with restricted mental health data from the National Cancer Institute.
- We establish the causal relationship between roadway noise and mental health, finding roadway noise has significant and detrimental effects on mental health through sleep deprivation.
- Beyond the haze of air pollution, this research highlights the often-overlooked but significant role that roadway noise plays in shaping mental health outcomes.

Data

- We utilize novel data that measure the exposure of approximately 14,000 individuals to roadway noise between 2014 and 2020.
- We use restricted H4C4 and H5C1 to H5C4 (HINTS) data because these 5 waves offer us valuable zip-9 information for random respondents at a national level.
- A unique feature of our data is that we can link individual mental health outcomes to roadway noise through relatively precise residential addresses (zip-9 information).

Data Continue

- We obtain noise data from the Department of Transportation's National Transportation Noise Maps (*DoT*) for 2016, 2018 and 2020, focusing on road noise.

- Other data sources: weather data from NCEI; $PM_{2.5}$ data from Shen et al.(2014); traffic-generated CO_2 emission data from NASA; clean energy usage data from DoE; census tract information from ACS.

- We also use Area and Road Ruggedness Scales data from USDA. It provides measures of topographic variation, or "ruggedness," for census tracts across 50 States and Washington, DC.

- This data provides the first ruggedness measure with full nationwide coverage for the United States and is the first to provide a roads-only version to help study the impact of rugged terrain on travel by car.

Data Description

- The key outcome variable is a summary mental health index (**PHQ-4**) for each respondent in the HINTS data. The index ranges from 0 to 12 with a larger number indicating worse mental health (*PHQ-4 questions*).

- The key independent variable is the local road noise pollution at the 9-digit zip code level, which measures exposure at a "several households" or "street" level (*noise measurement*).

- We control for individual demographic information like gender, race, education, and income.

- Based on the mental health literature, we also include detailed controls for individual physical health conditions and local environmental conditions.

Identification Strategy: Instrumental Variable Approach

- The ambient road noise is not randomly assigned, respondents may sort to live in specific areas based on their socioeconomic conditions.

- Another challenge is how to disentangle the effect of noise pollution from air pollution. We control for general air pollution (i.e. 1km-$PM_{2.5}$) and approximate potential concomitant air pollution (*DARTE*) to capture a more accurate effect of noise pollution.

- We address the endogeneity of noise and traffic-related air pollution by using some exogenous natural factors like the Terrain Ruggedness Index (TRI) and wind conditions.

- We argue that the variation in local topographic conditions and the number of days with different prevailing wind directions could generate different noise exposure for respondents.

IV Mechanism

- Noise, as a wave, requires channels to propagate through the air, and wind-related conditions can alter this process.
- These same wind conditions are also well-documented in the literature as affecting air pollution, allowing us to address both noise and its concomitant air pollution.
- Additionally, the local area ruggedness index influences drivers' behavior, particularly driving speeds, which impacts noise pollution through the friction between tires and roads.
- By incorporating these instruments, we address the endogeneity of roadway noise and its concomitant air pollution simultaneously.

Main Results

	Dependent variable:			
	Standardized mental health index			
	OLS	*IV Approach*		
Panel A: Air pollution within 1 km	(1)	(2)	(3)	(4)
Road noise	0.0016**	0.0026**	0.0077*	0.0117*
	(0.0008)	(0.0012)	(0.0045)	(0.0067)
CO_2 emission	0.0002	0.0042	0.0110	0.0130
	(0.0009)	(0.0033)	(0.0085)	(0.0129)
$PM_{2.5}$ concentration	-0.0022	0.0033	-0.0371	-0.0318
	(0.0093)	(0.0142)	(0.0277)	(0.0365)
Panel B: Air pollution within 5 km				
Road noise	0.0016*	0.0025**	0.0077*	0.0121*
	(0.0008)	(0.0012)	(0.0044)	(0.0065)
CO_2 emission	0.0019	0.0120**	0.0134	0.0115
	(0.0023)	(0.0053)	(0.0095)	(0.0118)
$PM_{2.5}$ concentration	-0.0032	-0.0042	-0.0347	-0.0320
	(0.0098)	(0.0144)	(0.0270)	(0.0349)
Instrument Variables				
County × wind direction		X		
State × wind direction			X	
Census Division × wind direction				X
Other instruments		X	X	X
County FE	X	X	X	X
Year FE	X	X	X	X
R^2 (Panel A)	0.198	0.122	0.110	0.097
R^2 (Panel B)	0.198	0.123	0.119	0.111
Observations	14,033	14,033	14,033	14,033
Note:				*p<0.1; **p<0.05; ***p<0.01

See first stage results here.

Robustness Check: Hearing Impaired Sub-sample

- HINTS includes a question on hearing impairment: "Are you deaf or do you have serious difficulty hearing?" Approximately 7%-9% of all respondents answered "Yes" to this question across the five waves.
- We run a "placebo test" by comparing the group of respondents who are hearing impaired with those who are not.
- We extract a sub-sample of senior citizens (60+ years) from the general population without any hearing impairment.
- We also have another sub-sample of hearing-impaired and non-impaired respondents from the counties where the hearing-impaired respondents reside by survey year.

Hearing Impaired Sub-sample Results

	Dependent variable:			
	Standardized mental health index			
	HI	NHI	ENHI	Comparable sample
	(1)	(2)	(3)	(4)
Road noise	−0.0033	0.0023*	0.0021	0.0044**
	(0.0076)	(0.0013)	(0.0018)	(0.0020)
CO_2 emission 1km	0.0026	0.0061*	0.0007	0.0044
	(0.0071)	(0.0032)	(0.0038)	(0.0040)
$PM_{2.5}$ concentration 1km	0.0221	−0.0003	−0.0183	0.0106
	(0.0647)	(0.0160)	(0.0238)	(0.0169)
Demographics	X***	X***	X***	X***
Health Indices	X***	X***	X***	X***
Weather	X	X	X	X
County FE	X	X	X	X
Year FE	X	X	X	X
R^2	0.159	0.121	0.100	0.117
Observations	583	10,469	3,906	10,690
Note:				*p<0.1; **p<0.05; ***p<0.01

Go to Clean Energy Check

- Reminder: The sum of observations in columns 1 and 2 does not add up to the full sample of 14,033 because the hearing-impaired question was not surveyed in 2019.

Mechanism

- There is some evidence suggesting that the deleterious effect of noise works mainly through the activation of a specific part of the brain, the hypothalamic pituitary adrenal (HPA) axis.

- We find that road noise has significantly negative effects on respondents' sleep duration. The sleep duration will be reduced by around 26 minutes when a respondent's average road noise exposure within his county increases by 10 dB.

- However, we do not find any significant effects of air pollution on sleep duration.

Sleep Results

	Dependent variable:
	Average sleep hours
Average road noise	-0.041^{*}
	(0.021)
Average CO_2 emission	-0.0014
	(0.0067)
Average $PM_{2.5}$ concentration	-0.0061
	(0.0097)
Constant	11.215^{***}
	(1.152)
Demographics	X***
Health Indices	X***
City Level	X
Housing Ownership	X
R^2	0.036
Observations	8,628
Note:	*p<0.1; **p<0.05; ***p<0.01

Implications

- Researchers find that even going from having "no" to "little" or "little" to "mild" depressive symptoms could lower labor incomes and increase the unemployment rate (Germinario et al. 2022; Peng et al. 2016).

- Our findings for the deleterious effect are equivalent to a 10% increase in the number of respondents experiencing mild mental health symptoms.

- Our back-of-the-envelope calculation based on Germinario et al.'s estimates suggests a 13 billion dollar (in 2021 dollars) total welfare loss from ambient road noise.

- Policymakers may investigate the noise abatement investment/policy to protect people from the negative effects of noise pollution.

Conclusion

- We estimate the causal effect of roadway noise on mental health using restricted individual-level data with noise measurement at a 9-digit zip code level.
- We find that road noise has significant negative effects on mental health.
- We find that sleep deprivation plays a significant role in explaining how noise affects mental health.

Acknowledgement

- We appreciate Richard Moser and all his colleagues at NIH/NCI who approve our usage of the restricted HINTS data.

- We appreciate the Department of Economics at SUNY-Binghamton for granting Neha Khanna the faculty research funding for us to purchase zip-9 geographic information from GeoLytics.

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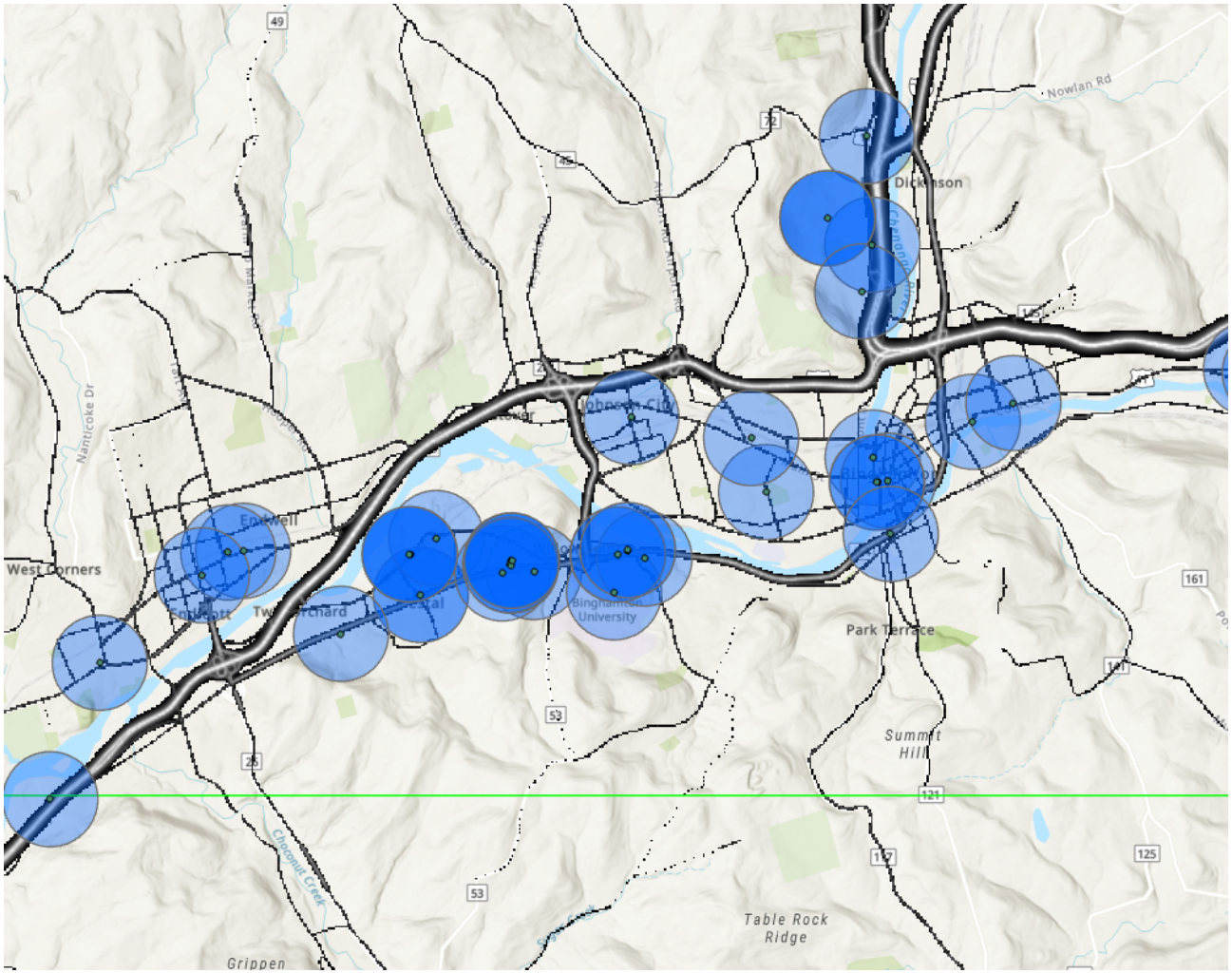
PHQ-4 Questions

This summary index consists of the answers to four separate mental health-related questions. The questions are respectively: *over the past 2 weeks*, how often have you been bothered by any of the following problems?

- 1. Little interest or pleasure in doing things;
- 2. Feeling down, depressed or hopeless;
- 3. Feeling nervous, anxious, or on edge;
- 4. Not being able to stop or control worrying.

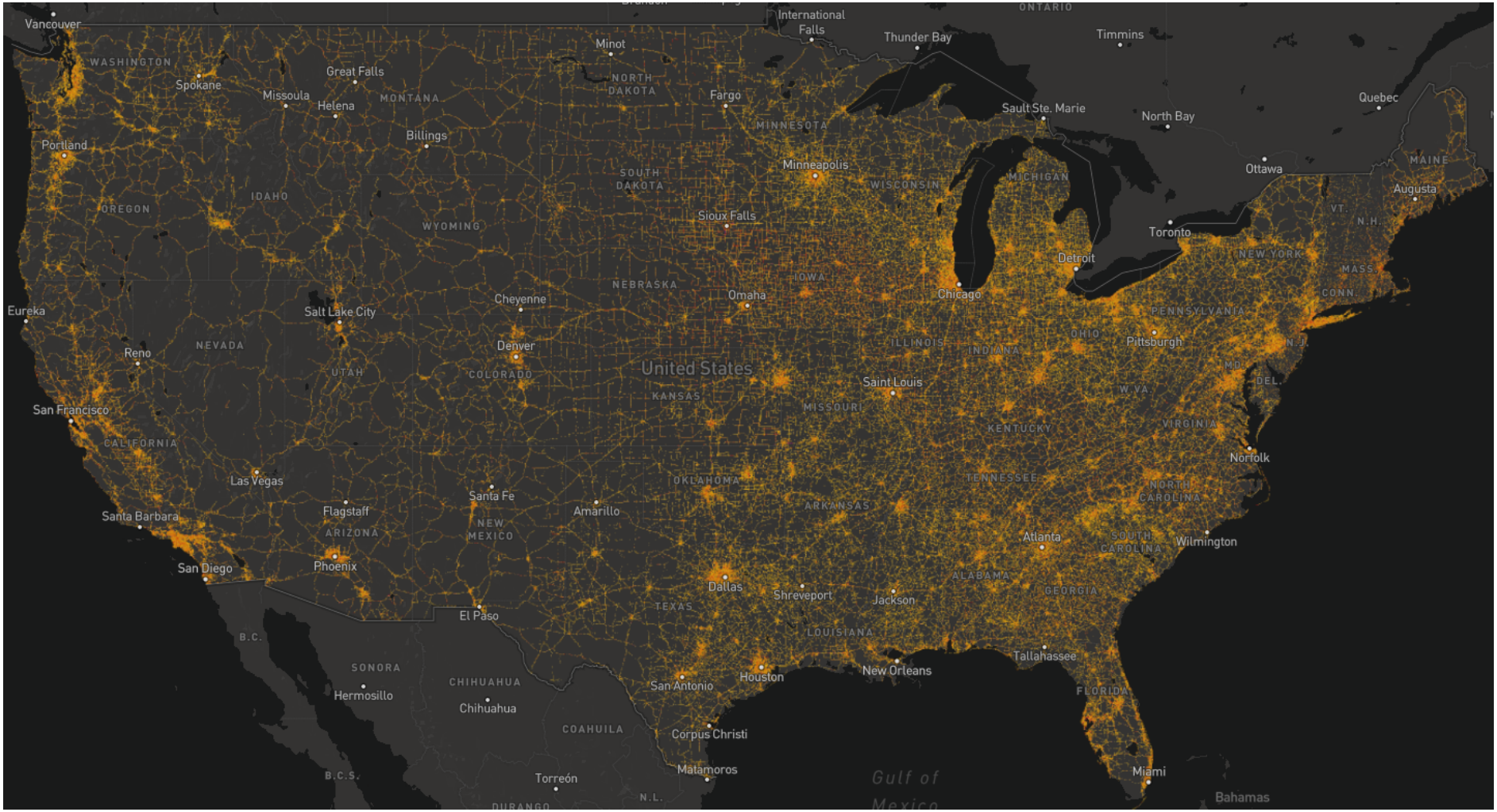
Go to Data Description

Within Buffer Noise Measurement



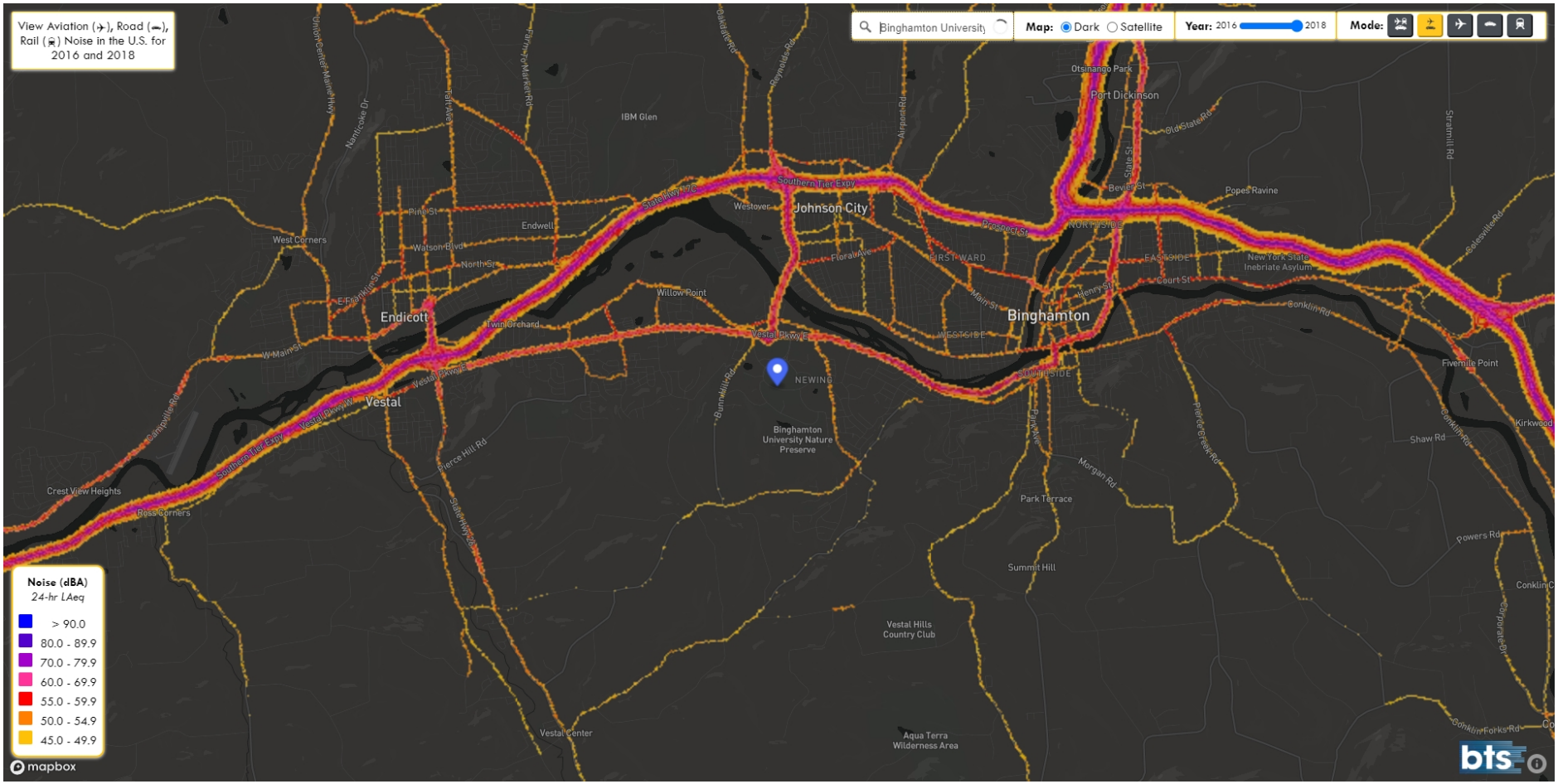
Go to Data Description

DoT Noise Map



Zoom in

Binghamton University Noise Map



We can see I-81/86 and Route 17 clearly here!
Go to Data

First Stage Results

	Dependent variable:								
	Road noise	*CO_2 emission*	*$PM_{2.5}$*	*Road noise*	*CO_2 emission*	*$PM_{2.5}$*	*Road noise*	*CO_2 emission*	*$PM_{2.5}$*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Windspeed:	0.318**	0.211	-0.070***	0.416***	-0.028	-0.062***	0.338***	-0.031	-0.056***
	(0.129)	(0.153)	(0.011)	(0.117)	(0.107)	(0.009)	(0.114)	(0.103)	(0.009)
Windspeed Maximum:	-0.035	-0.095	-0.137***	-0.110	-0.009	-0.087***	-0.095	0.013	-0.080***
	(0.080)	(0.094)	(0.007)	(0.069)	(0.063)	(0.005)	(0.067)	(0.061)	(0.005)
Averagetemp:	0.408***	0.556***	0.065***	0.171	0.458***	0.073***	0.0169	0.463***	0.064***
	(0.113)	(0.134)	(0.009)	(0.106)	(0.097)	(0.008)	(0.104)	(0.094)	(0.008)
RoadTRI:	0.189***	0.066**	0.004**	0.237***	0.072***	0.005***	0.233***	0.075***	0.006***
	(0.022)	(0.026)	(0.002)	(0.023)	(0.021)	(0.002)	(0.023)	(0.021)	(0.002)
AreaTRI:	-0.165***	-0.062***	-0.011***	-0.211***	-0.062***	-0.012***	-0.209***	-0.064***	-0.012***
	(0.015)	(0.018)	(0.001)	(0.016)	(0.014)	(0.001)	(0.015)	(0.014)	(0.001)
F Statistic	3.73	0.48	4.09	3.86	3.47	20.33	7.63	8.98	47.14
County FE	X	X	X	X	X	X	X	X	X
Year FE	X	X	X	X	X	X	X	X	X
R^2	0.612	0.233	0.883	0.303	0.184	0.819	0.290	0.179	0.810
County × wind direction	X	X	X						
State × wind direction				X	X	X			
Census Division × wind direction							X	X	X
Observations	14,033	14,033	14,033	14,033	14,033	14,033	14,033	14,033	14,033

Note: *p<0.1; **p<0.05; ***p<0.01

First Stage Continue

First Stage Results Continue

	Dependent variable:		
	Road noise	*CO_2 emission*	*$PM_{2.5}$*
	(1)	(2)	(3)
Averagetemp:	0.197**	0.345***	0.015***
	(0.084)	(0.076)	(0.007)
RoadTRI:	0.232***	0.079***	0.007***
	(0.023)	(0.021)	(0.002)
AreaTRI:	-0.212***	-0.068***	-0.013***
	(0.015)	(0.014)	(0.001)
F Statistic	69.31	15.22	68.08
County FE	X	X	X
Year FE	X	X	X
R^2	0.288	0.177	0.794
Observations	14,033	14,033	14,033
Note:		*p<0.1; **p<0.05; ***p<0.01	

Go to Main Table

Database of Road Transportation Emissions (DARTE)

- DARTE provides a 1-km resolution inventory of annual on-road CO_2 emissions based on roadway-level vehicle traffic data and state-specific emissions factors for multiple vehicle types, we use it to approximate traffic air pollution (e.g. tailpipe emissions).

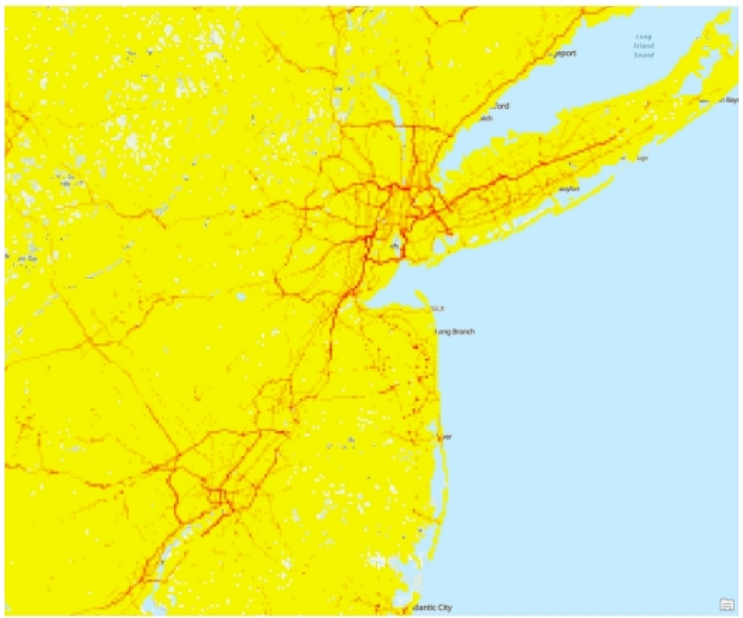


Figure A.2: CO_2 Emission Map

Note: We show the 2017 CO_2 emission map for New York City and its surrounding areas for brevity. The cells with a darker shade of red represent more traffic-generated CO_2 emissions. Notably, areas with detectable traffic-related CO_2 emissions tend to be fairly close to the highways.

Go to Identification Strategy

Confounding Air Pollutant Results

	Dependent variable:	
	Standardized mental health index	
	(1)	(2)
Road noise	0.0027**	0.0026**
	(0.0012)	(0.0012)
CO_2 emission 1km	0.0043	
	(0.0033)	
CO_2 emission 5km		0.0122**
		(0.0053)
$PM_{2.5}$ concentration 1km	0.0032	
	(0.0142)	
$PM_{2.5}$ concentration 5km		-0.0044
		(0.0144)
CSwpd×Road noise	-0.0083	-0.0095
	(0.0171)	(0.0170)
Demographics	X***	X***
Health Indices	X***	X***
Weather	X	X
County FE	X	X
Year FE	X	X
R^2	0.122	0.123
Observations	14,033	14,033
Note:	*p<0.1; **p<0.05; ***p<0.01	

Go to Robustness Check