Can Air Pollution Save Lives?
Air Quality and Risky Behaviors on Roads

Wen Hsu, Bing-Fang Hwang, Chau-Ren Jung, Yau-Huo (Jimmy) Shr*

Jan. 1st, 2022 @ AEA

* Hsu: Department of Finance, National Taiwan University
Hwang: Department of Occupational Safety and Health, China Medical University;
Jung: Department of Public Health, China Medical University;
Shr: Department of Agricultural Economics, National Taiwan University

THE ADVERSE EFFECTS OF AIR POLLUTION

- The socio-economic costs of air pollution (Currie and Walker, 2019)
- Health (e.g., Deryugina et al. 2019)
- Cognitive performance (both short-term and long-term)
  - Worker productivity (e.g., Archsmith et al. 2018, Chang et al. 2019, Graff Zivin and Neidell 2012, He et al. 2019, Lichter et al. 2017)
  - Test scores (Heissel et al. 2020, Lavy et al. 2014, Persico and Venator 2021)
  - Experiment tasks and cognitive functioning questions (Bedi et al. 2021, Lai et al. 2021)
- Risk aversion and investment behaviors (Chew et al. 2021, Levy and Yagil 2011, Li et al. 2019)
  - Cognitive ability is negatively associated with the degree of risk aversion (Dohmen et al. 2018)

AIR POLLUTION ON RISK PREFERENCES AND RISKY BEHAVIORS

- Some evidence from medical literature
  - Exposure to air pollution leads to increases stress hormone cortisol (Li et al. 2017)
  - Higher level of cortisol has been linked to higher degree of risk aversion (Coates et al. 2008, Kandasamy et al. 2014)
- Higher degree of risk aversion may reduce life-threatening risky behaviors, e.g., risky driving behaviors
- **Can air pollution lead to less traffic accidents through increased risk aversion and safer driving behaviors?**
  - It may also lead to more accidents through impaired cognition (or irritated respiratory system) and driving performance (Sager 2019)
  - Dose response between pollution and cognition/risk aversion may be nonlinear

RESEARCH QUESTION AND KEY FINDINGS

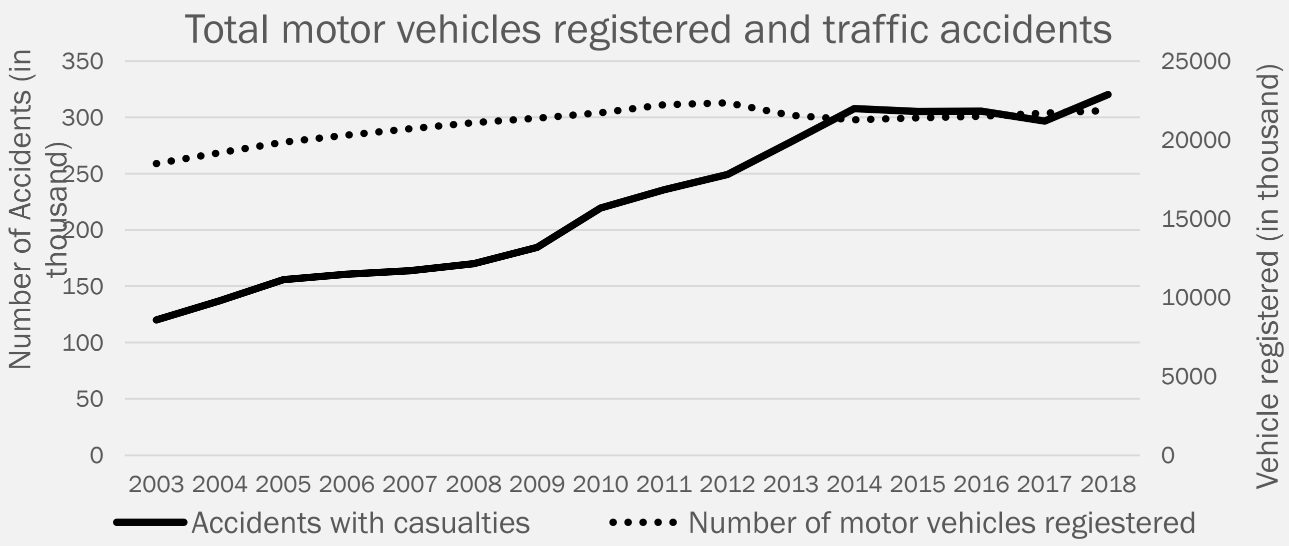
- We study the impacts of air quality on accidents ***caused by driver violations*** using administrative data from Taiwan between 2009 – 2015
- We find a 1 μg/m^3 increase in $PM_{2.5}$ concentration leads to a 0.59% ***decrease*** in the total number of traffic accidents caused by violations w/ casualties
  - The reduction is unlikely explained by avoidance behavior
  - No significant effect on accidents caused by harmless lapses
  - The negative effect increases with the level of pollution
  - The negative effect is only observed when air quality can be easily assessed visually (i.e., in daytime)

KEY FINDINGS AND IMPLICATIONS

- The cost of air pollution on cognitive performance and other associated health outcomes involving risk attitudes may be biased (or underestimated, if cognitive performance and risk aversion are negatively correlated)
  - He et al. (2019) find that air pollution decreases worker productivity by making workers take more breaks.
- The nonlinear dose-responses to air pollution
- The determinants of risk attitudes (e.g., Dohmen et al. 2011)
- The stability of risk preferences (Schildberg-Hörisch 2018)

TRAFFIC ACCIDENTS IN TAIWAN

- In 2010, there were nearly 220,000 traffic accidents involving casualties with an estimated costs of about $14 billion USD (Jou et al. 2019)
  - More than 300,000 accidents with 1,696 deaths and 410,073 injuries in 2015
  - More than 340,000 accidents with 1,849 deaths (8 per 100,000 pop) and 456,378 (1984 per 100,000 pop) injuries in 2019



TRAFFIC ACCIDENTS IN TAIWAN AND THE U.S.

- In 2010, there were nearly 220,000 traffic accidents involving casualties with an estimated costs of about $14 billion USD (Jou et al. 2019)
  - More than 340,000 accidents with 1,849 deaths (8 per 100,000 pop) and 456,378 (1984 per 100,000 pop) injuries in 2019
- In the U.S., the estimated costs from 5.42 million crashes were $871 billion in 2010 (NHTSA, 2015)
- 36,096 deaths (11 per 100,000 pop) and 2.74 million injuries (835 per 100,000 pop) from nearly 2 million motor vehicle crashes in 2019 (NHTSA, 2020)
- Motor vehicle crashes are one of the leading causes of death in the U.S. for people under 55 (the leading cause before 2010) (CDC, 2020)

DATA

- Administrative traffic accident data between 2009 and 2015
  - 1.76 million accidents with 17,412 deaths (in two days) and 2.35 million injuries
  - 1.12 million contribute to driver violations

Daily Accidents Caused by Violations per District/Township	Mean	S.D.	Min	Max	Total
All	1.27	2.22	0	33	1,126,395
By non-enclosed vehicle drivers	0.60	1.26	0	20	534,493
With natural light	0.89	1.61	0	24	787,990
Fair-weather and good visibility	1.04	1.99	0	29	926,417
During rush hours	0.54	1.10	0	16	482,955
At intersections	0.84	1.60	0	25	744,665
By female drivers	0.41	0.93	0	15	366,026

Notes: Mean, S.D., min, and max are based on 888,736 observations from each day of each of all 365 districts and townships between 2009 – 2015.

DATA

- Administrative traffic accident data between 2009 and 2015
- Daily air quality ($PM_{2.5}$) data at district/township level, averaged from air quality data at 3km*3km grid resolution (Wang et al. 2020)
  - (1) Aerosol optical depth (AOD) retrievals from MODerate resolution Imaging Spectroradiometer (MODIS); (2) Land use data from National Land Surveying and Mapping Center; (3) Real time ground $PM_{2.5}$ measurement and long-term emission grid data from Taiwan EPA
- We also estimate the following atmospheric condition variables — rainfall, temperature, humidity, wind speed, and ***wind directions*** — for each district/township with spatial inverse distance weighting from the three nearest EPA's air quality monitoring stations

DATA

Air Quality and Atmospheric Conditions	Mean	S.D.	Min	Max
$PM_{2.5}$ ($\mu g/m^3$)	27.06	15.81	0.36	241.41
Avg. Temp. ($^\circ$C)	21.76	5.11	4.36	31.32
Rainfall (mm/hr)	0.20	0.71	0.00	32.50
Rain hours (hr)	2.47	4.38	0.00	24.00
Relative Humidity (%)	81.37	7.94	44.59	99.60
Wind Speed (m/s)	2.23	1.13	0.32	16.11
East Wind (%)	29	23	0	100
South Wind (%)	19	20	0	100
West Wind (%)	25	18	0	100
North Wind (%)	27	24	0	100

Notes: Mean, S.D., min, and max are based on 888,736 observations from each day of each of all 365 districts and townships between 2009 – 2015.

EMPIRICAL STRATEGY: FIXED EFFECT MODEL

- Poisson regression with spatial and temporal fixed effects by pseudo maximum likelihood (Silva and Tenreyro 2006, Correia et al. 2020)

$$Acc_{it} = \exp(\beta AQ_{it} + \boldsymbol{\theta}'\boldsymbol{X}_{it} + \boldsymbol{\omega_{it}}) + \varepsilon_{it}$$

  - Acc_{it} is the traffic accident related count in district/township i in day t
  - AQ_{it} is the air quality measure
  - $\boldsymbol{X}_{it}$ is a vector of weather condition controls
  - $\boldsymbol{\omega_{it}}$ are spatial and temporal fixed-effects (district/township, year, month, day of week)
    - The fixed effects control for factors such as traffic volume, with seasonal and within-week variations for each region
    - The standard errors are clustered at district/township and day of year to accommodate spatial and temporal autocorrelations

AIR POLLUTION AND ACCIDENTS CAUSED BY VIOLATIONS (FE)

Variables	(1) PPML	(2) PPML	(3) PPML	(4) PPML	(5) OLS
$PM_{2.5}$ ($\mu g/m^3$)	0.0092***	0.0120***	-0.0010***	-0.0009***	-0.0012***
	(0.0016)	(0.0021)	(0.0002)	(0.0001)	(0.0002)
Semi-Elasticity					-0.0009
Observations	892,044	888,736	886,182	820,358	888,736
Weather Controls	N	Y	Y	Y	Y
Town FE	N	N	Y	N	N
Year-Month FE	N	N	Y	N	N
DoW FE	N	N	Y	N	N
Town-Year-Month FE	N	N	N	Y	Y
Town-DoW FE	N	N	N	Y	Y
Pseudo R^2 / Adj-R^2	0.008	0.015	0.468	0.465	0.734

Notes: The outcome variable is the total number of accidents caused by violations in each district/township. Weather controls include the linear and squared terms of daily average temperature, relative humidity, per hour rainfall, hours of rain, and wind speed. Standard errors are in parenthesis and clustered at number of day and district/township level. *, **, ***: significant at 5%, 1%, and 0.1%

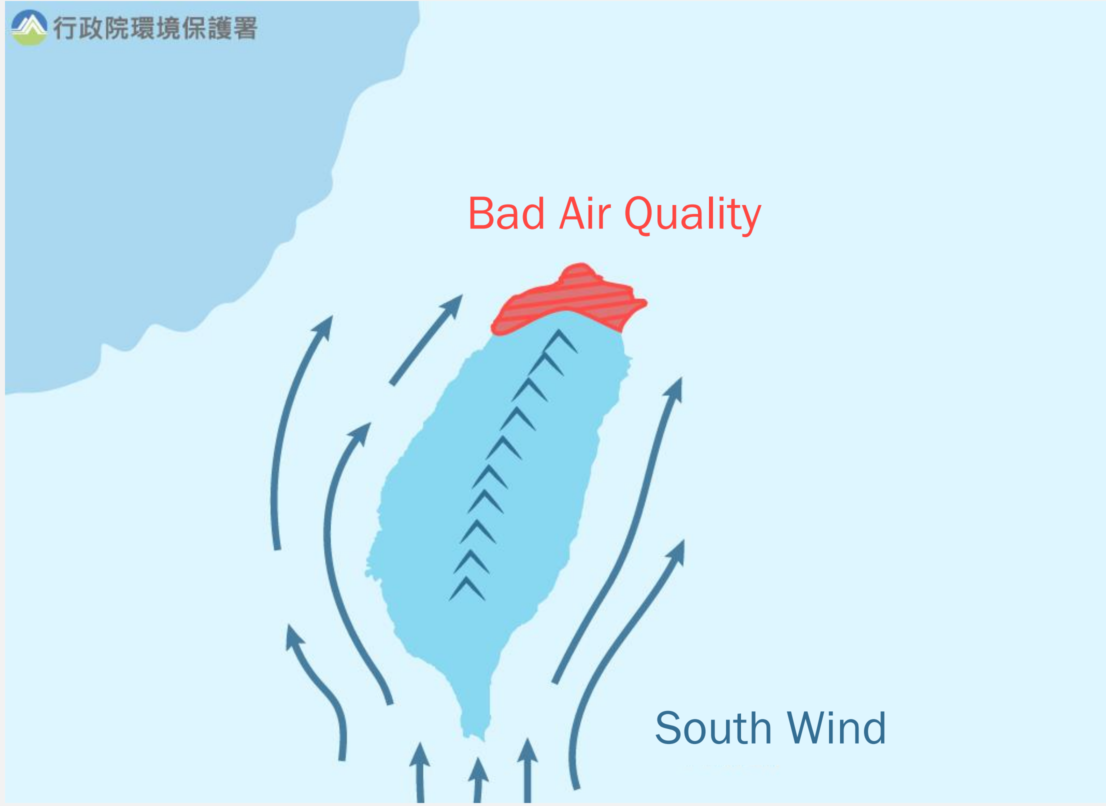
THE ENDOGENEITY BETWEEN POLLUTION AND ACCIDENTS

- Omitted variables: e.g., the variations in traffic volumes not controlled by the fixed effects
- Avoidance behaviors: individuals decide not to travel because of a high level of air pollution (Moretti and Neidell, 2011)
- Reverse causality: traffic accidents may lead congestion and more (exposure to) pollution
- We use ***wind directions*** as instrumental variables to introduce exogenous variation in air quality (Anderson 2020, Deryugina et al. 2019, Bondy et al. 2020)

THE ENDOGENEITY BETWEEN POLLUTION AND ACCIDENTS

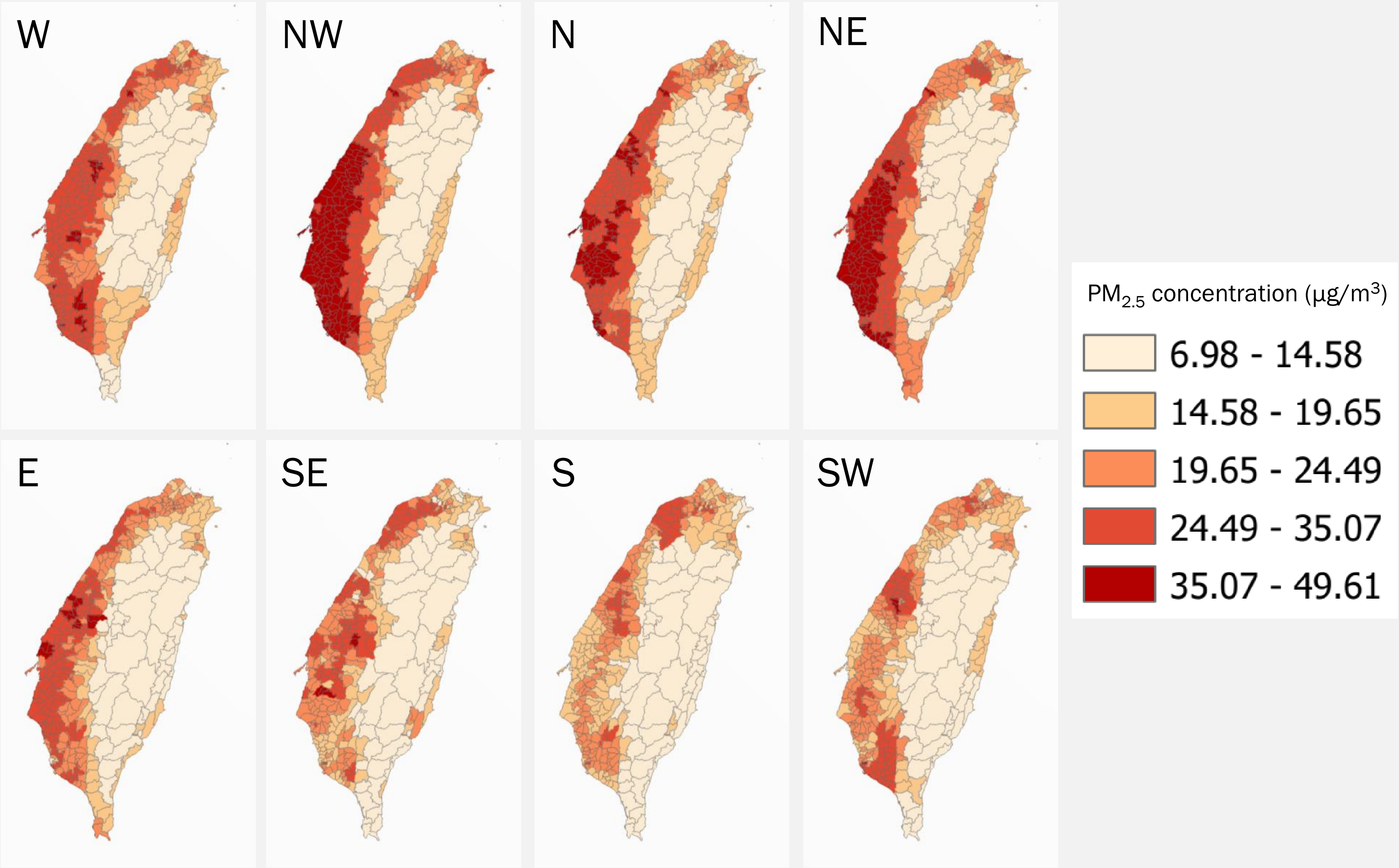
- We use ***wind directions*** as instrumental variables to introduce exogenous variation in air quality (Anderson 2020, Deryugina et al. 2019, Bondy et al. 2020)
- Assumptions for a valid instrument:
  - Relevance: wind direction affects air quality in Taiwan (Shie et al., 2016)
  - Exclusion restriction: wind direction would *only* affect road risk behaviors and accidents through changing air quality (arguably true when weather conditions are controlled for)
  - Independence: wind direction is independent from the errors of accidents on air pollution
  - Monotonicity: the effects of wind direction on air pollution are monotone

WIND DIRECTIONS AND AIR QUALITY IN TAIWAN



Source: Taiwan EPA at https://airtw.epa.gov.tw/cht/Encyclopedia/pedia02/pedia2.aspx

WIND DIRECTIONS AND AIR POLLUTION



THE ENDOGENEITY BETWEEN POLLUTION AND ACCIDENTS

- We use ***wind direction*** as an instrumental variable to introduce exogenous variation in air quality (Anderson 2020, Deryugina et al. 2019, Bondy et al. 2020)
- Assumptions for a valid instrument:
  - Relevance: wind direction affects air quality in Taiwan (Shie et al., 2016)
  - Exclusion restriction: wind direction would *only* affect road risk behaviors and accidents through changing air quality (arguably true when weather conditions are controlled for)
  - Independence: wind direction is independent from the errors of accidents on air pollution
  - Monotonicity: the effects of wind direction on air pollution are monotone

EMPIRICAL STRATEGY: CONTROL FUNCTION APPROACH

- The first stage

$$AQ_{it} = \boldsymbol{\gamma'_q AQZ_{iq} WD_{it}} + \boldsymbol{\delta' X_{it}} + \boldsymbol{\omega_{it}} + \upsilon_{it}$$

  - AQ_{it}: the air quality (pollutant) measure in district/township i in day t
  - $\boldsymbol{AQZ_{iq}} = 1$ if district/township i is in air quality zone q
  - $\boldsymbol{WD_{it}}$ is the share of hours in the 24-hour period in which wind blows from a certain direction
  - $\boldsymbol{X_{it}}$ are weather condition variables (temperature, precipitation, humidity, and wind speed)
  - $\boldsymbol{\omega_{it}}$ are spatial and temporal fixed-effects (district/township, year by month, day of week)

FIRST STAGE (AIR POLLUTION ON WIND DIRECTIONS)

Variables (WD by AQ Zone)	(1) OLS	(2) OLS	(3) OLS
South Wind x AQ Zone North	0.7096	3.7565**	-0.3776
	(1.9483)	(1.3526)	(1.4463)
South Wind x AQ Zone Central	-2.7817*	-3.3785***	-3.1097***
	(1.2435)	(0.7933)	(0.8555)
South Wind x AQ Zone South	-10.1895***	-4.1085***	0.2931
	(0.9363)	(0.9309)	(1.0165)
South Wind x AQ Zone East	-12.1673***	-0.5219	-5.8214***
	(1.2571)	(0.9196)	(0.7752)
West Wind x AQ Zone North	3.6997**	6.2390***	4.7087***
	(1.1534)	(0.7854)	(0.8303)
West Wind x AQ Zone Central	8.1869**	3.1903***	2.4498*
	(2.9403)	(0.7910)	(0.9891)
West Wind x AQ Zone South	15.7092***	2.1208*	4.9465***
	(1.4134)	(0.9456)	(1.0416)
West Wind x AQ Zone East	-1.7700	-7.4636***	-5.7200***
	(1.3314)	(0.9962)	(1.0923)
North Wind x AQ Zone North	1.0580	3.6321**	1.5687
	(1.0308)	(1.1696)	(1.3506)
North Wind x AQ Zone Central	16.9963***	-1.6744*	-5.2331***
	(1.3061)	(0.6817)	(0.8904)
North Wind x AQ Zone South	26.7380***	10.0435***	9.0299***
	(1.6625)	(1.0584)	(1.1472)
North Wind x AQ Zone East	-4.5505*	-4.1387***	-3.2284**
	(1.8290)	(1.0475)	(1.0639)
Observations	892,044	888,736	888,736
Weather Controls	N	Y	Y
Town FE	N	Y	N
Year-Month FE	N	Y	N
DoW FE	N	Y	N
Town-Year-Month FE	N	N	Y
Town-DoW FE	N	N	Y
K-P F-statistics	99.67	46.27	31.31
R-squared	0.221	0.617	0.656

EMPIRICAL STRATEGY: CONTROL FUNCTION APPROACH

- For a nonlinear second stage with Poisson regression, we adopt the control function (Wooldridge, 2015)

$$Acc_{it} = \exp(\beta AQ_{it} + \gamma \widehat{v_{it}} + \boldsymbol{\theta}' \boldsymbol{X}_{it} + \boldsymbol{\omega_{it}}) + \varepsilon_{it}$$

  - Acc_{it} is the traffic accident related count in region i within a time period t
  - $\widehat{v_{it}}$ is the residual $(AQ_{it} - \widehat{AQ_{it}})$ from the first stage
  - $\boldsymbol{X}_{it}$ is a vector of weather condition variables
  - $\boldsymbol{\omega_{it}}$ are spatial and temporal fixed-effects

* Control function is likely more efficient but less robust than 2SLS

AIR POLLUTION AND ACCIDENTS CAUSED BY VIOLATIONS (IV)

Variables	(1) IV PPML	(2) IV PPML	(3) IV PPML	(4) IV OLS	(5) IV PPML
$PM_{2.5}$ ($\mu g/m^3$)	-0.0013	-0.0056***	-0.0059***	-0.0070***	-0.0059***
	(0.0065)	(0.0012)	(0.0012)	(0.0016)	(0.0012)
Semi-Elasticity				-0.0055	
$PM_{2.5}$ (1 day before)					0.0001
					(0.0002)
$PM_{2.5}$ (2 days before)					0.0000
					(0.0002)
$PM_{2.5}$ (3 days before)					0.0004*
					(0.0002)
Observations	892,044	886,182	820,358	888,736	820,355
Weather Controls	N	Y	Y	Y	Y
Town FE	N	Y	N	N	N
Year-Month FE	N	Y	N	N	N
DoW FE	N	Y	N	N	N
Town-Year-Month FE	N	N	Y	Y	Y
Town-DoW FE	N	N	Y	Y	Y
K-P F-statistics	99.67	46.27	31.31	31.31	31.31

ROBUSTNESS CHECKS

- Are the negative effects driven by avoidance behaviors?
  - Rush hours (7 – 10AM & 5 – 8PM) vs. non-rush hours
  - Weekdays vs. Weekend
  - District/Township by population density (lower vs. upper 50%)
- Are the negative effects driven by increased risk aversion?

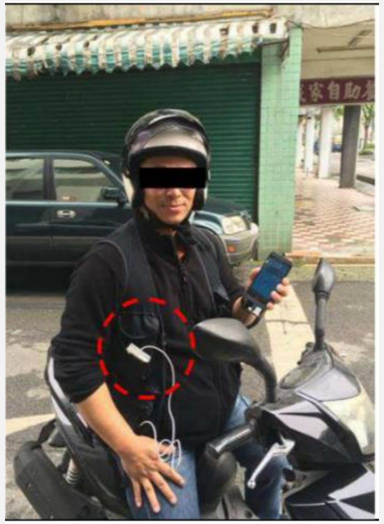
Variables	Rush Hours	Non-rush Hours	Weekdays	Weekend	Regions w/ Low Pop	Regions w/ High Pop	Mindless Errors
$PM_{2.5}$	-0.0068***	-0.0052***	-0.0060***	-0.0060**	-0.0064*	-0.0057***	-0.0032
	(0.0017)	(0.0013)	(0.0014)	(0.0023)	(0.0032)	(0.0013)	(0.0019)
Observations	763,893	789,956	568,466	211,482	375,139	445,219	776,785

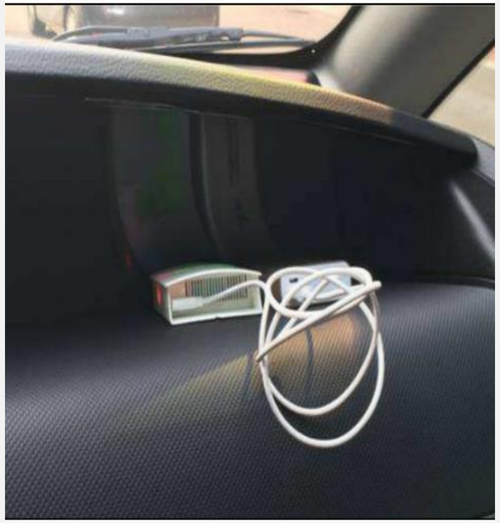
ADDITIONAL ROBUSTNESS CHECKS

	(1) Linear Weather		(2) Eight Wind Directions		(3) Four Wind Direction and Wind Speed		(4) County Level		(5) Fair Weather & Good Visibility	
Variables	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
$PM_{2.5}$	-0.0069***	(0.0011)	-0.0055***	(0.0009)	-0.0046***	(0.0006)	-0.0069*	(0.0029)	-0.0061***	(0.0018)
Observations	820,358		820,358		820,358		48,518		804,604	
Weather Controls (Linear terms)	Y		Y		Y		Y		Y	
Weather Controls (Quadratic terms)	N		Y		Y		Y		Y	
Town-Year-Month FE	Y		Y		Y		N		Y	
Town-DoW FE	Y		Y		Y		N		Y	
County-Year-Month FE	N		N		N		Y		N	
County-DoW FE	N		N		N		Y		N	
K-P F-statistics	34.02		19.27		55.39		23.95		31.31	

TRANSMISSION CHANNELS: RESPIRATORY AND VISUAL

- Motorcyclists and scooter drivers have been found to experience higher level of air pollution, compared to car drivers. (Tsai et al, 2008; Dirks et al., 2012; Vlachokostas et al., 2012)
- The average $PM_{2.5}$ concentrations that commuters in Taipei using car and motorcycle/scooter exposed to are 7.6 and 32.1 ug/m^3, respectively (Taiwan EPA, 2017)





TRANSMISSION CHANNELS: RESPIRATORY AND VISUAL

- Motorcyclists and scooter drivers have been found to experience higher level of air pollution, compared to car drivers.
- If air pollution affect road risky behaviors through respiratory channel, we hypothesize that air pollution would reduce the number of accidents caused by violations committed by non-enclosed vehicle drivers more than those by enclosed vehicle drivers.

Variables	(1) Enclosed Vehicle	(2) Non-enclosed Vehicle	(3) Natural Light	(4) No Natural Light
$PM_{2.5}$	-0.0057***	-0.0067***	-0.0079***	-0.0018
	(0.0016)	(0.0016)	(0.0015)	(0.0018)
Observations	781,092	762,527	807,090	698,196

TRANSMISSION CHANNELS: RESPIRATORY AND VISUAL

- Gloomy day has been linked to higher risk aversion (e.g., Bassi et al. 2013, Kliger and Levi 2003, Saunders 1993, Shafi and Mohammadi 2020)

- What if it is dark out? When there is little ambient light, air pollutants (particular matters) will have little effect on light attenuation and be much less visible (Hyslop 2009, Yu et al. 2018)
- Note that we assume the air quality is not bad enough to affect driving through impaired visibility

TRANSMISSION CHANNELS: RESPIRATORY AND VISUAL

- If air pollution affect road risky behaviors through visual channel, we hypothesize that the effect would be stronger during times with ambient natural light than during times without.
- A placebo test: the effect of ozone, which is generally found to the smallest effect on hazy skies among all major air pollutants (Liu et al. 2020)

Variables	(1) Enclosed Vehicle	(2) Non-enclosed Vehicle	(3) Natural Light	(4) No Natural Light
$PM_{2.5}$	-0.0057***	-0.0067***	-0.0079***	-0.0018
	(0.0016)	(0.0016)	(0.0015)	(0.0018)
Observations	781,092	762,527	807,090	698,196

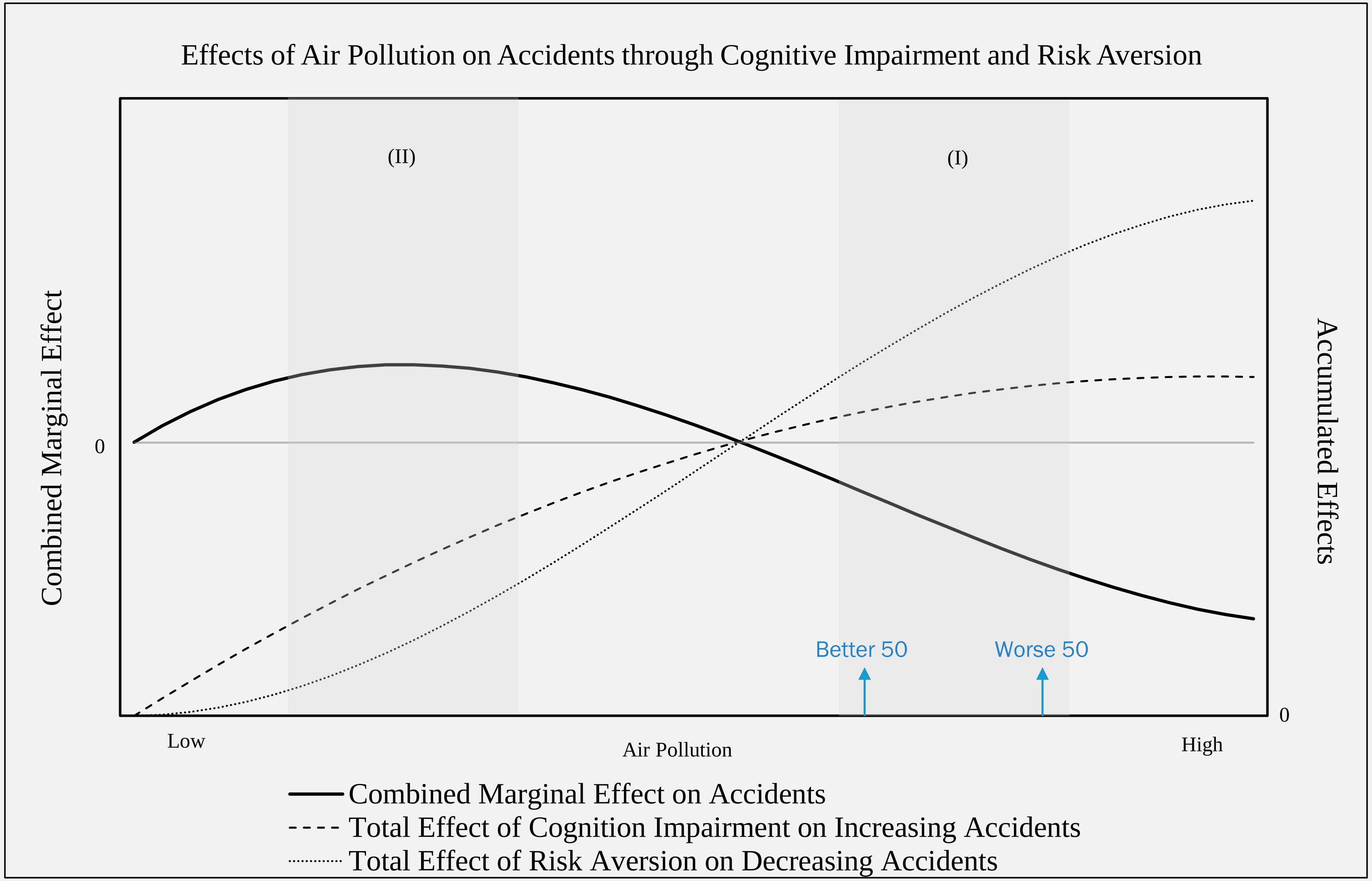
Variables	(1) All
Ozone (ppm)	-0.0003
	(0.0008)
Observations	820,345

THE NONLINEAR EFFECTS OF AIR POLLUTION ON RISKY BEHAVIORS

- Based on each region's average $PM_{2.5}$ concentration, we stratify all regions into two groups (the better and worse 50) using the sample median of daily average $PM_{2.5}$ concentration of the entire study period as the cutoff.
- Nonlinear second stage with linear splines (Henderson and Souto 2018, Wooldridge 2015)

Variables	(1) Better 50	(2) Worse 50	(3) $PM_{2.5}$ Splines
$PM_{2.5}$	-0.0026 (0.0025)	-0.0062*** (0.0014)	
$PM_{2.5}$ (0 – 10 μg/m^3)			0.0060 (0.0046)
$PM_{2.5}$ (10 – 20 μg/m^3)			-0.0073*** (0.0015)
$PM_{2.5}$ (20 – 30 μg/m^3)			-0.0063*** (0.0013)
$PM_{2.5}$ (30 μg/m^3 and above)			-0.0054*** (0.0012)
Observations	378,385	441,973	820,358

THE NONLINEAR EFFECTS ON COGNITION AND RISK PREFERENCES



HETEROGENEOUS EFFECTS: BY GENDER AND AGES

- Gender and age are two of the key characteristics for explaining an individual's risk tolerance (e.g., Borghans et al. 2009, Halek and Eisenhauer 2001, Hartog et al. 2002).
- The smaller negative effect of air pollution among elderlies once again suggests that avoidance behaviors against air pollution cannot explain the reduction in accidents.

	(1)	(2)	(3)	(4)	(5)
Variables	Female	Male	Under 40	40 to 64	65 and Above
$PM_{2.5}$	-0.0058**	-0.0059***	-0.0061***	-0.0062**	-0.0034
	(0.0018)	(0.0013)	(0.0017)	(0.0019)	(0.0031)
Observations	715,911	806,257	659,313	651,161	541,750

CONCLUSIONS

- We find that a 1 $\mu g/m^3$ increase in $PM_{2.5}$ concentration leads to a 0.59% decrease in accidents caused by driver violations.
- A nonlinear dose-response relationship between air pollution and risky behaviors: air pollution likely increases the degree of risk aversion at an increasing rate (or at a rate faster than that on reducing cognition).
- The cost of air pollution on cognitive performance and other associated health outcomes involving risk attitudes may be biased, if the effect on risk attitudes is not isolated.
- Air pollution can affect risk preferences through visual channel: the negative effects are only observed in times when air quality can be visually assessed.

APPENDIX: AIR POLLUTION AND ACCIDENTS (COMPLETE RESULTS)

	(1)		(2)		(3)		(4)	
	IV PPML		IV PPML		IV PPML		IV OLS	
Variables	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
$PM_{2.5}$	-0.0013	(0.0065)	-0.0056***	(0.0012)	-0.0059***	(0.0012)	-0.0070***	(0.0016)
Temp. (˚C)			0.0071	(0.0058)	0.0013	(0.0055)	-0.0020	(0.0074)
$[\text{Temp. (°C)}]^2$			-0.0000	(0.0001)	0.0001	(0.0001)	0.0002	(0.0002)
Rainfall (mm/hr)			-0.0230**	(0.0071)	-0.0211**	(0.0070)	-0.0276***	(0.0078)
$[\text{Rainfall (mm/hr)}]^2$			-0.0013	(0.0009)	-0.0014	(0.0009)	-0.0005	(0.0006)
Rain hours (hr)			-0.0044**	(0.0014)	-0.0045**	(0.0015)	-0.0056**	(0.0017)
$[\text{Rain hours (hr)}]^2$			-0.0000	(0.0001)	-0.0000	(0.0001)	-0.0001	(0.0001)
Relative Humidity (%)			0.0036	(0.0038)	0.0037	(0.0040)	-0.0003	(0.0054)
$[\text{Relative Humidity (\%)}]^2$			-0.0001*	(0.0000)	-0.0001*	(0.0000)	-0.0000	(0.0000)
Wind Speed (m/s)			0.0263*	(0.0106)	0.0071	(0.0098)	0.0068	(0.0115)
$[\text{Wind Speed (m/s)}]^2$			-0.0044**	(0.0014)	-0.0022	(0.0013)	-0.0016	(0.0010)
Constant	0.2561	(0.1772)	1.0812***	(0.1526)	1.1928***	(0.1497)	1.6914***	(0.2168)
Observations	892,044		886,182		820,358		888,736	
Weather Controls	N		Y		Y		Y	
Town FE	N		Y		N		N	
Year-Month FE	N		Y		N		N	
DoW FE	N		Y		N		N	
Town-Year-Month FE	N		N		Y		Y	
Town-DoW FE	N		N		Y		Y	
K-P F-statistics	99.67		46.27		31.31		31.31	

APPENDIX: AIR POLLUTION AND TRAFFIC VOLUME IN TAIPEI CITY

	(1) Linear		(2) Quadratic		(3) Splines	
Variables	Coefficient	SE	Coefficient	SE	Coefficient	SE
$PM_{2.5}$	0.0047	(0.0035)	0.0047	(0.0033)		
$(PM_{2.5})^2$			0.0000	(0.0000)		
$PM_{2.5}$ (0 – 10 μg/m^3)					0.0029	(0.0036)
$PM_{2.5}$ (10 – 20 μg/m^3)					0.0062	(0.0034)
$PM_{2.5}$ (20 – 30 μg/m^3)					0.0021	(0.0050)
$PM_{2.5}$ (30 μg/m^3 and above)					0.0072	(0.0034)
Observations	11,154		11,154		11,154	

Notes: The outcome variable is the logged daily total traffic volume by town (district) in Taipei City, 2018 to 2020. All models control for Town-Year-Month and Town-DoW fixed effects as well as weather controls including the linear and squared terms of daily average temperature, relative humidity, per hour rainfall, hours of rain, and wind speed. $PM_{2.5}$ concentration is instrumented by wind directions. The first-stage K-P F-statistic is 22.12. Standard errors are in parenthesis and clustered at number of day and district/township level. All the coefficients of $PM_{2.5}$ are not significant at 5% level.