Air Pollution in Bangkok:
Status, Causes & Economic Effects

Witsanu Attavanich

Faculty of Economics, Kasetsart University

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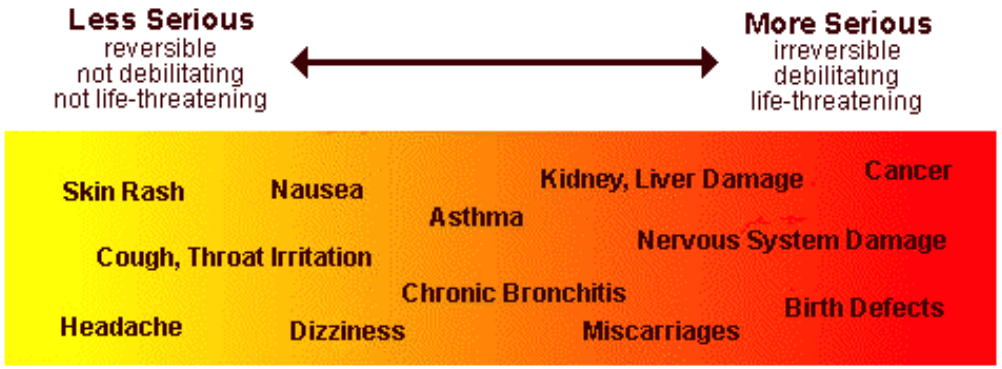
Outline

- Introduction
- Status of Air Pollution
- Determinants of Air Pollution
- Economic Effects
- Policy Recommendations

Introduction

- Past studies revealed that people living in the urban areas are *highly likely* to be faced with health risks caused by air pollution (WHO, 2018)
- Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide in 2016
- Some 91% of those premature deaths occurred in low- and middle-income countries, and the greatest number in the WHO South-East Asia and Western Pacific regions
- Bangkok is one of the cities located in a middle-income country facing problems associated with poor air quality

Introduction



Source: https://www3.epa.gov/airtoxics/3_90_022.html

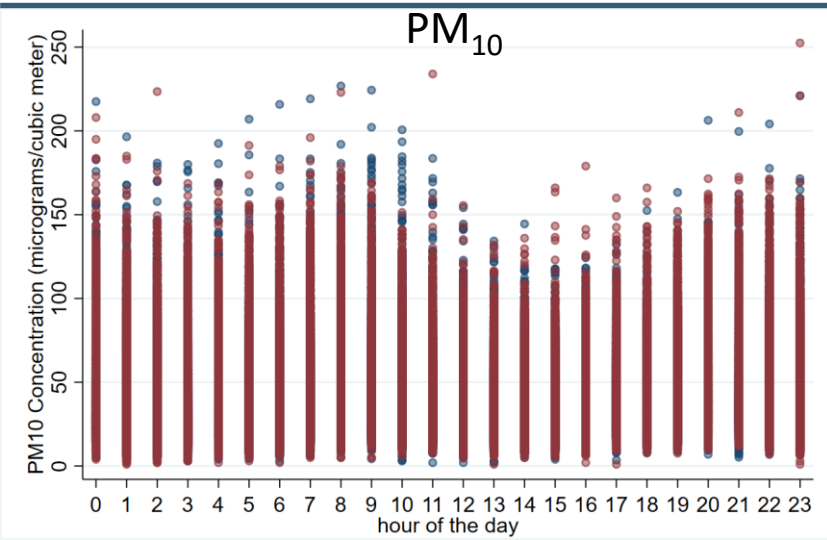
- Health Effects:
  - Particulate Matter ($PM_{2.5}$ & PM_{10})
    - Cardiovascular and respiratory disease, and cancers
    - Increased mortality or morbidity, both daily and over time
  - Ozone (O_3)
    - Breathing problems, asthma, lung function and lung diseases
  - Nitrogen dioxide (NO_2)
    - Bronchitis in asthmatic children and lung function growth
  - Sulfur dioxide (SO_2)
    - Respiratory system, lung functions, eye irritation, asthma and chronic bronchitis

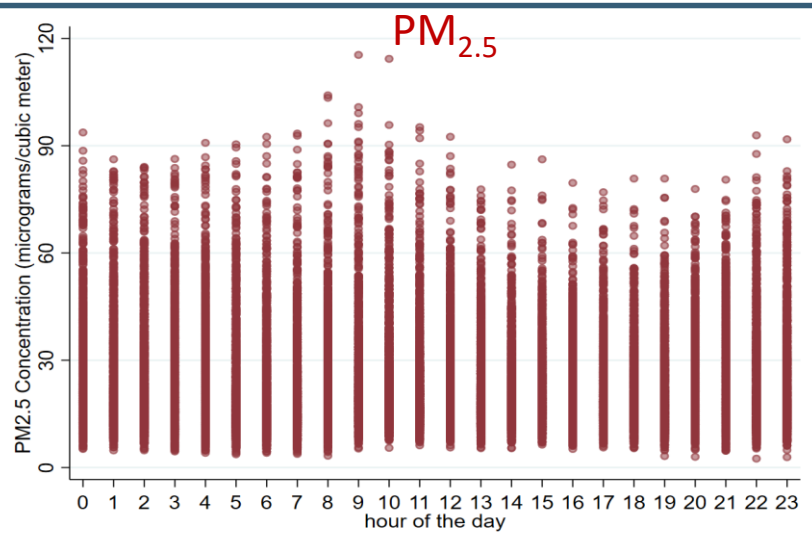
Introduction

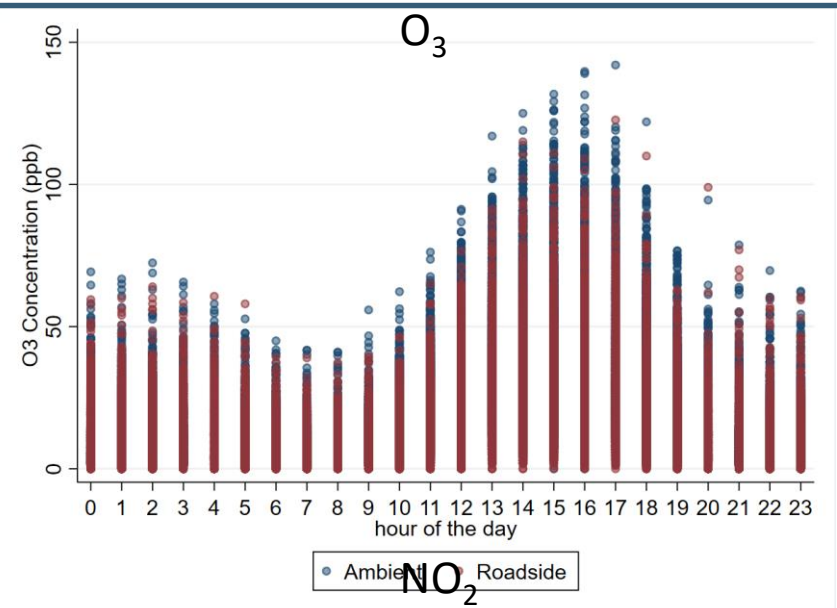
- While air pollution has caused serious health effect, no previous study completely quantifies the economic cost of air pollution in Bangkok
- This study aims to…
  - provide status and analyze determinants of air pollution in Bangkok
  - evaluate the corresponding economic damage generated by air pollution
- This article contributes to the air pollution literature in several aspects:
  - Findings can shed some light on the economic cost of air pollution
  - The current study is among the first to assess the willingness to pay to reduce air pollution in Bangkok, nation wide, and all provinces
  - Government can use findings (determinants and economic damage) as information to explore appropriate solutions to improve air quality

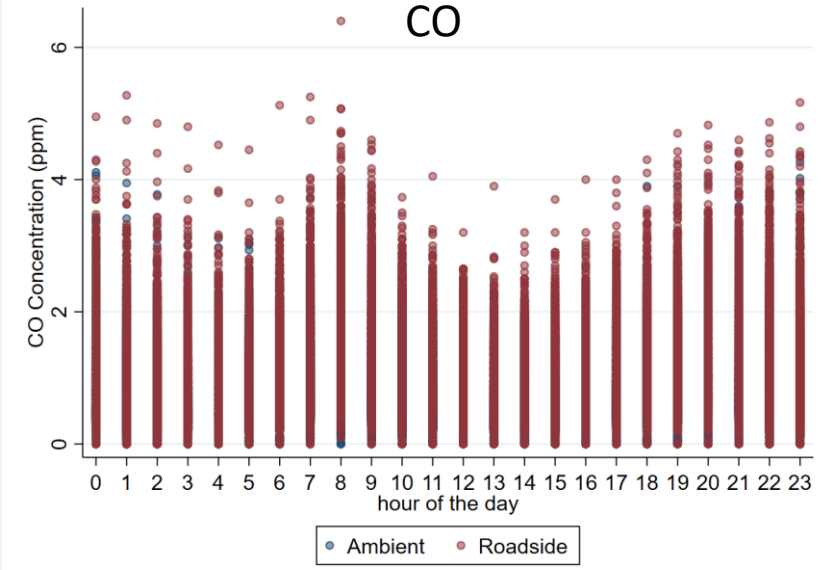
Status of Air Pollution in Bangkok

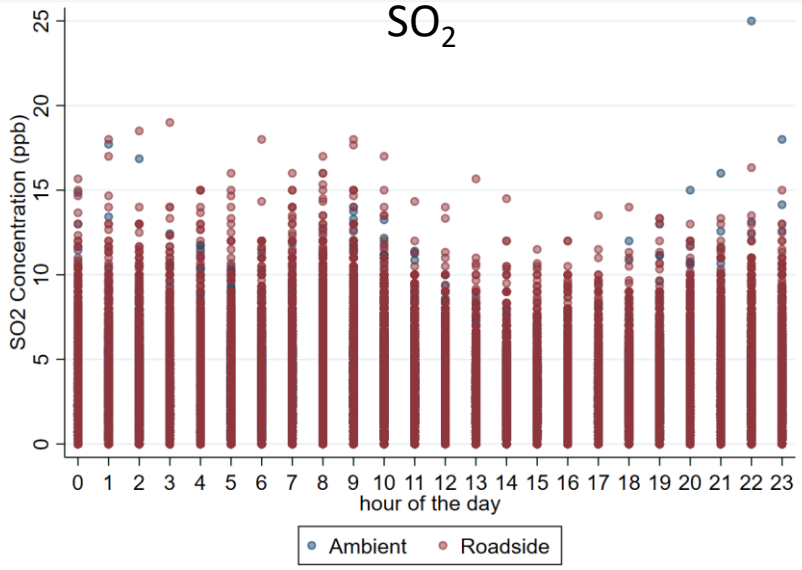
Hourly Pollution

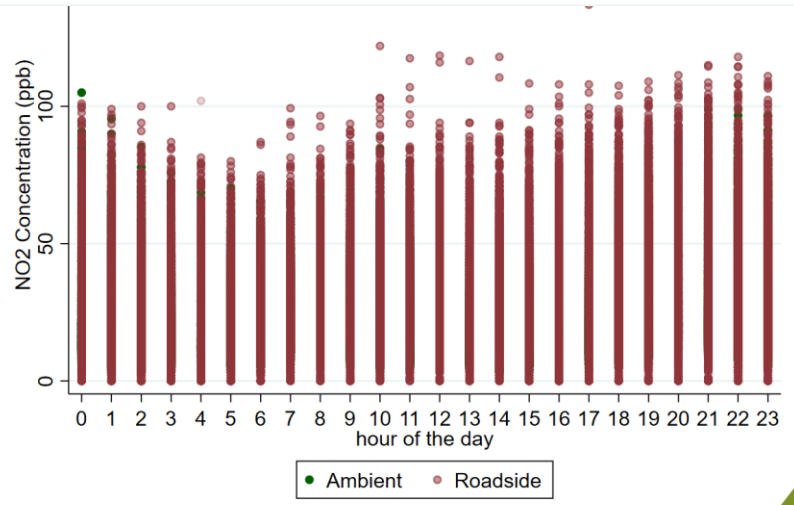








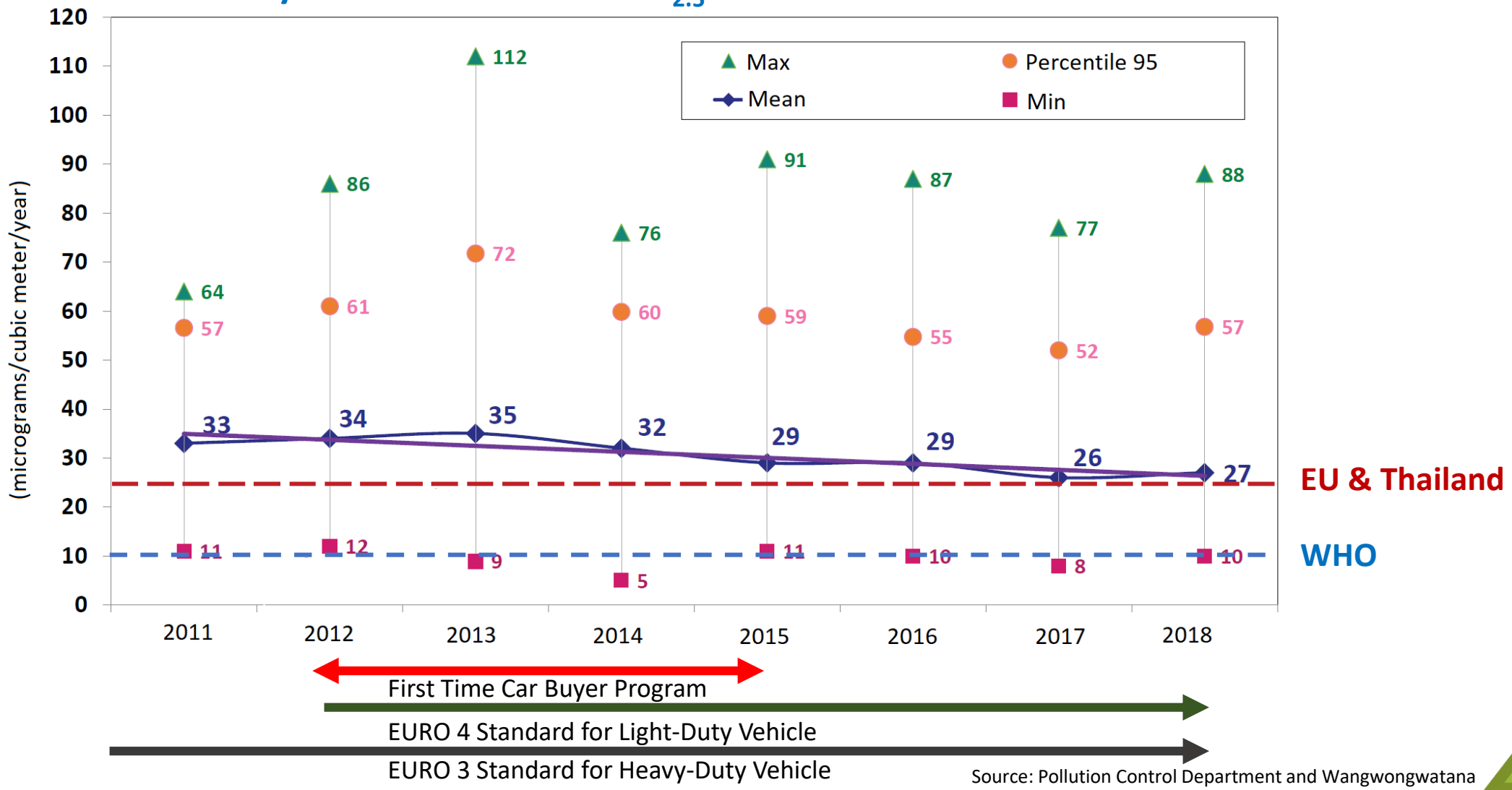




Status of Air Pollution in Bangkok

$PM_{2.5}$ Status

Summary Statistics of Annual $PM_{2.5}$

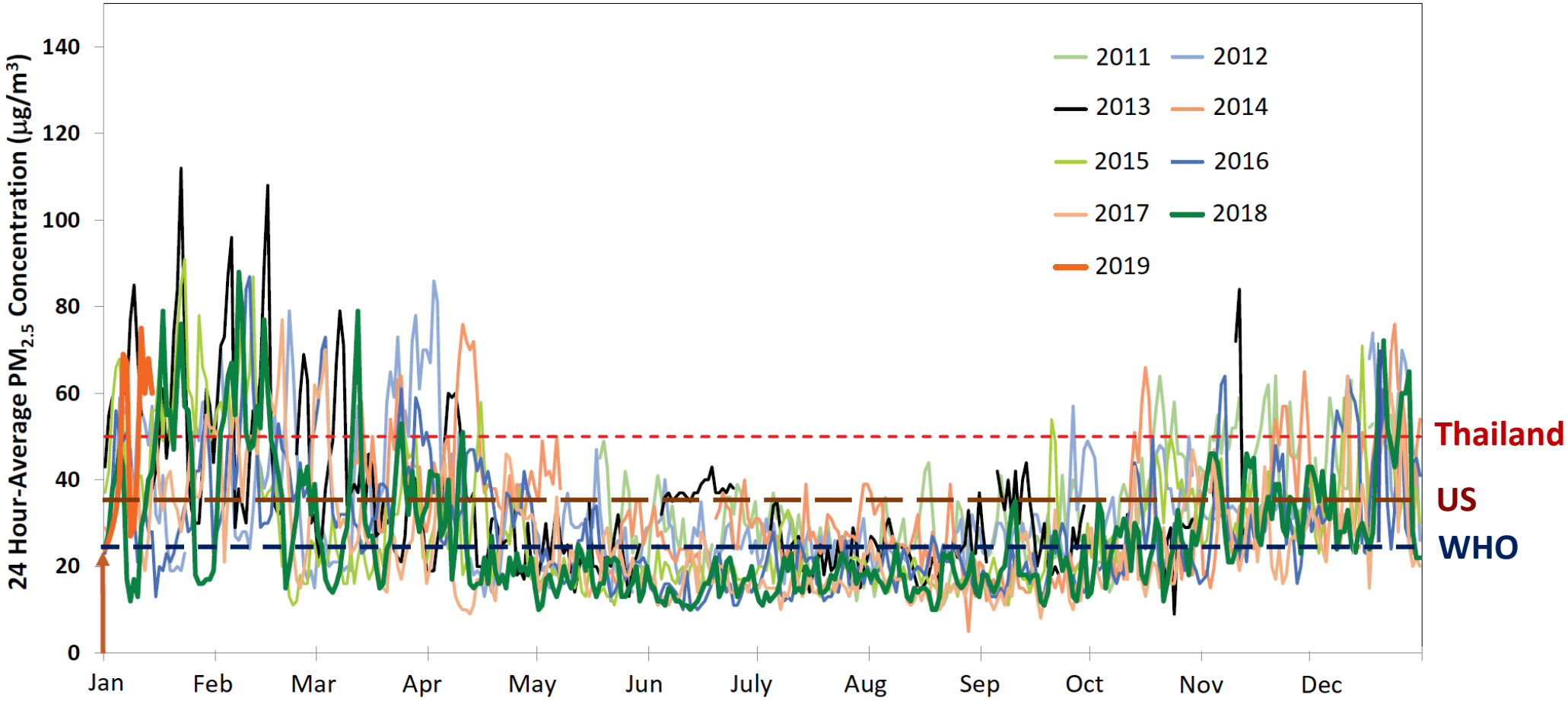


Source: Pollution Control Department and Wangwongwatana

Status of Air Pollution in Bangkok

$PM_{2.5}$ Status

Summary Statistics of 24-Hour Average of $PM_{2.5}$

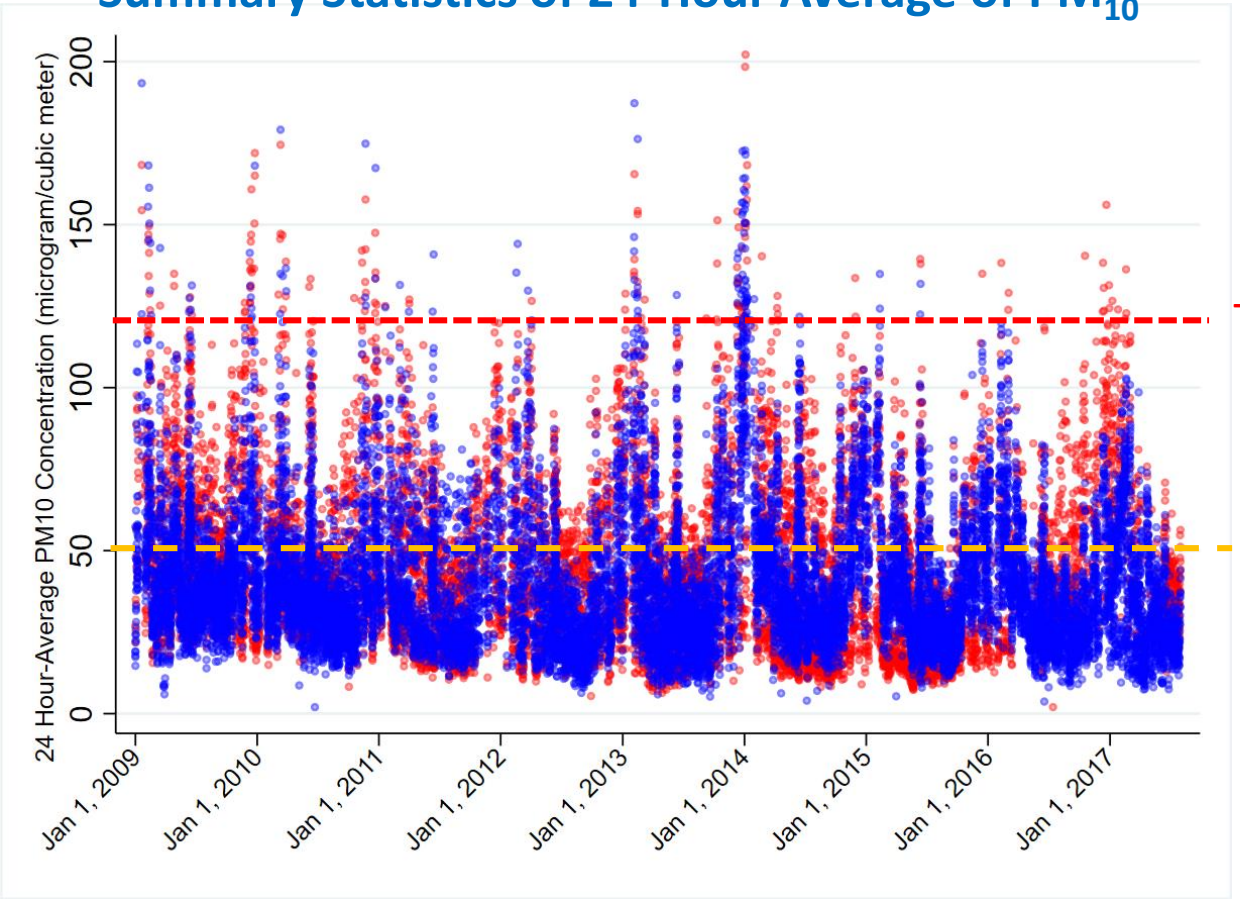


Source: Pollution Control Department and Wangwongwatana

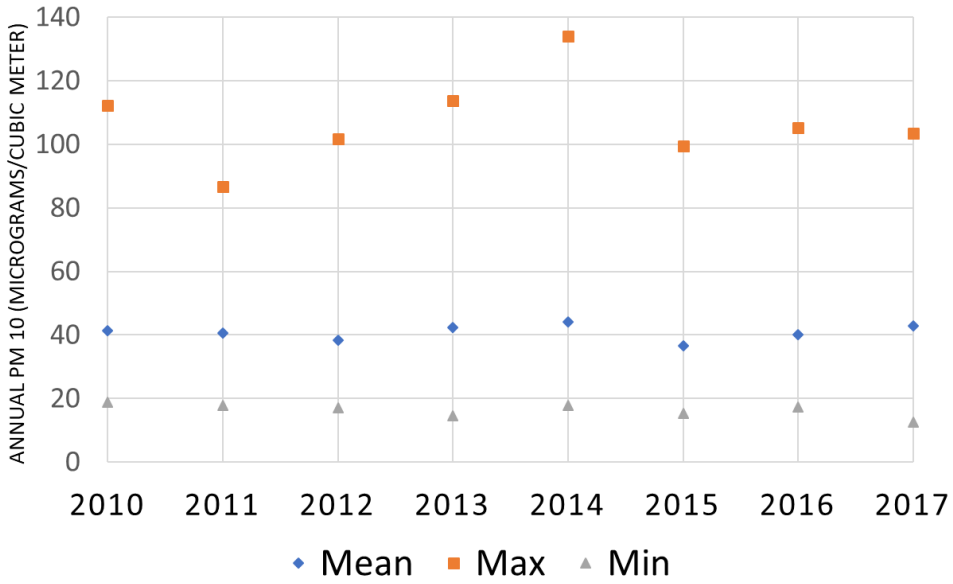
Status of Air Pollution in Bangkok

PM_{10}

Summary Statistics of 24-Hour Average of PM_{10}



Year	Days (exceed>50 micrograms)
2010	72
2011	78
2012	72
2013	96
2014	105
2015	64
2016	77



Note: Mean EU standard is 40 micrograms/cubic meter
Mean WHO guideline is 20 micrograms/cubic meter

Determinants of Air Pollution

- Hourly air pollution data from 13 monitoring stations were collected from Pollution Control Department
  - Roadside and ambient
- Seemingly Unrelated Regression (Zellner, 1962) and Prais–Winsten regression (Prais–Winsten,1954) were used for estimations during different time periods
  - 1 October 2009 to 31 September 2014
  - 1 April 2010 to 31 March 2014 (Suggested by Davis, 2008)
  - 1 January 2009 to 31 December 2017

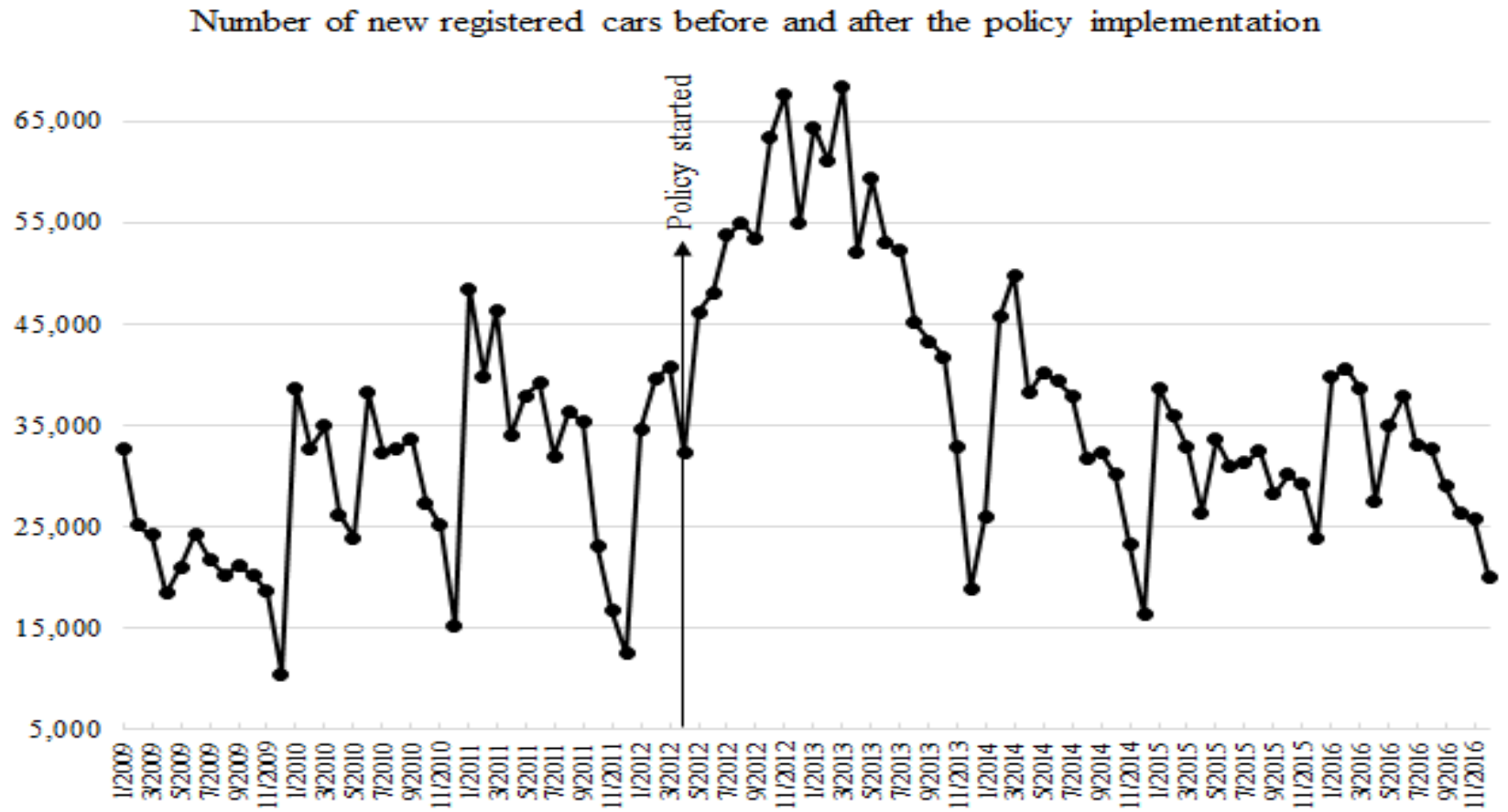
Determinants of Air Pollution

ตัวแปร	PM10	SO2	NO2	CO	O3
T	-0.000418***	-0.000159***	-0.000186***	-1.01e-05***	-0.000272***
	(3.24e-05)	(2.04e-06)	(1.78e-05)	(5.78e-07)	(1.55e-05)
First	281.8***	9.956***	24.15***	2.375***	69.60***
	(10.02)	(0.630)	(5.499)	(0.179)	(4.781)
*First*T*	-0.0174***	-0.000547***	-0.00152***	-0.000137***	-0.00389***
	(0.000607)	(3.82e-05)	(0.000333)	(1.08e-05)	(0.000290)
Euro4	-299.0***	-11.15***	-17.46***	-2.295***	-69.87***
	(10.01)	(0.630)	(5.495)	(0.179)	(4.778)
*Euro4*T*	0.0183***	0.000683***	0.00132***	0.000135***	0.00420***
	(0.000608)	(3.82e-05)	(0.000333)	(1.08e-05)	(0.000290)
Feb	-9.136***	-0.630***	-7.873***	-0.197***	3.317***
	(0.465)	(0.0293)	(0.255)	(0.00829)	(0.222)
Mar	-17.47***	-1.201***	-10.79***	-0.269***	1.669***
	(0.522)	(0.0328)	(0.286)	(0.00930)	(0.249)
Dec	-4.810***	-0.191***	-2.567***	-0.118***	-1.220***
	(0.435)	(0.0274)	(0.239)	(0.00776)	(0.208)

First car buyer program, EURO4 standard, and month of the year affect concentration of pollutants

Determinants of Air Pollution

- First car buyer program implemented during 2012-2015



Source: Attavanich (2017)

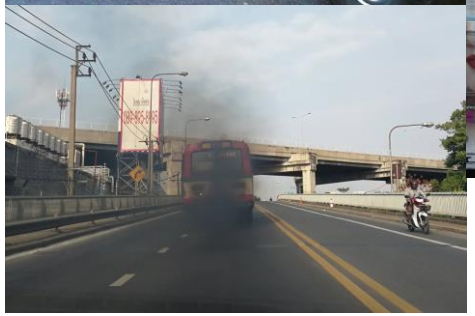
Determinants of Air Pollution

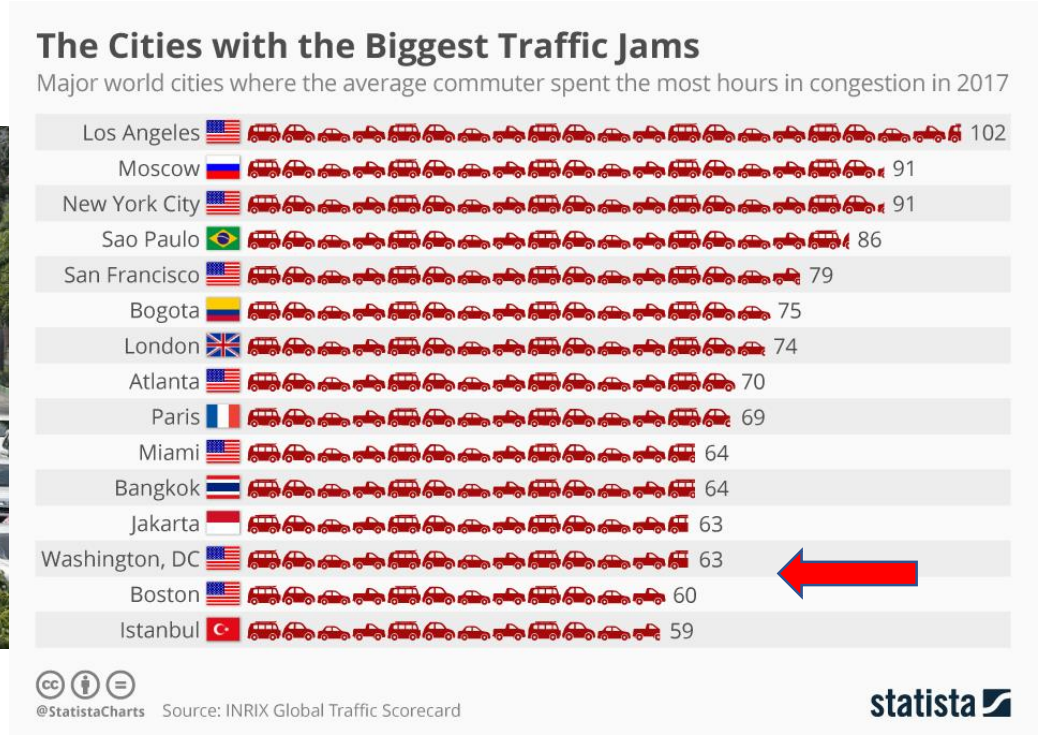
ตัวแปร	PM10	SO2	NO2	CO	O3
Weekday	2.125**	0.255***	1.341***	0.0200	-0.475
	(0.892)	(0.0561)	(0.490)	(0.0159)	(0.426)
Hourofday 7	1.714	0.493***	-4.424***	-0.0263	-0.982*
	(1.070)	(0.0673)	(0.587)	(0.0191)	(0.511)
Hourofday 8	5.247***	0.693***	-3.402***	0.0489**	-1.049**
	(1.068)	(0.0672)	(0.586)	(0.0191)	(0.510)
Hourofday 9	3.911***	0.704***	-2.530***	0.0376**	-0.166
	(1.067)	(0.0671)	(0.585)	(0.0190)	(0.509)
Hourofday 18	0.777	-0.201***	1.360**	0.0455**	8.374***
	(1.080)	(0.0679)	(0.593)	(0.0193)	(0.515)
Hourofday 19	3.767***	-0.114*	3.422***	0.115***	4.315***
	(1.073)	(0.0675)	(0.589)	(0.0191)	(0.512)
Hourofday 20	6.210***	-0.0200	5.187***	0.154***	1.003**
	(1.069)	(0.0673)	(0.587)	(0.0191)	(0.510)
Hourofday 21	6.132***	0.0289	5.364***	0.156***	-0.628
	(1.067)	(0.0672)	(0.586)	(0.0190)	(0.509)
Hourofday 22	4.086***	0.0177	4.303***	0.122***	-1.170**
	(1.067)	(0.0671)	(0.585)	(0.0190)	(0.509)

- Weekday > Weekend
- Each hour of the day has different levels of pollutant's concentrations

Determinants of Air Pollution

- **Findings are consistent to scientific literature that burning fossil fuels is a major source of air pollution**





Determinants of Air Pollution

- **Burning fossil fuels and toxic materials in the production process of factories without good treatment**

Determinants of Air Pollution

ตัวแปร	PM10	SO2	NO2	CO	O3
Bigflood	-1.154*	-0.456***	-3.834***	-0.310***	-1.416***
	(0.627)	(0.0394)	(0.344)	(0.0112)	(0.299)
Temperature	-11.23***	-0.0428	-2.618***	-0.111***	2.400***
	(0.436)	(0.0274)	(0.239)	(0.00778)	(0.208)
Temp sq	0.169***	-0.000139	0.0215***	0.00156***	-0.0312***
	(0.00776)	(0.000488)	(0.00426)	(0.000138)	(0.00370)
Rainfall	-1.131***	-0.200***	-0.880***	-0.0564***	0.807***
	(0.168)	(0.0106)	(0.0921)	(0.00299)	(0.0801)
Rainfall sq	0.0543***	0.00912***	0.0383***	0.00229***	-0.0255***
	(0.0125)	(0.000788)	(0.00688)	(0.000224)	(0.00598)
Relativehumid	0.784***	0.0435***	0.428***	-0.00204*	-2.145***
	(0.0640)	(0.00402)	(0.0351)	(0.00114)	(0.0305)
Humid sq	-0.00854***	-0.000433***	-0.00454***	4.73e-05***	0.0128***
	(0.000456)	(2.87e-05)	(0.000250)	(8.13e-06)	(0.000218)
Windspeed	-39.07***	-1.511***	-35.88***	-0.666***	4.853***
	(1.697)	(0.107)	(0.931)	(0.0303)	(0.810)
Windsp sq	9.942***	0.216***	8.322***	0.163***	-2.995***
	(0.637)	(0.0401)	(0.350)	(0.0114)	(0.304)
Observations	35,064	35,064	35,064	35,064	35,064
R-squared	0.427	0.396	0.514	0.407	0.734

- Big flood reduced the concentrations of pollutants
- Temperature, rainfall, relative humidity, wind speed and wind direction determine levels of pollutant's concentrations

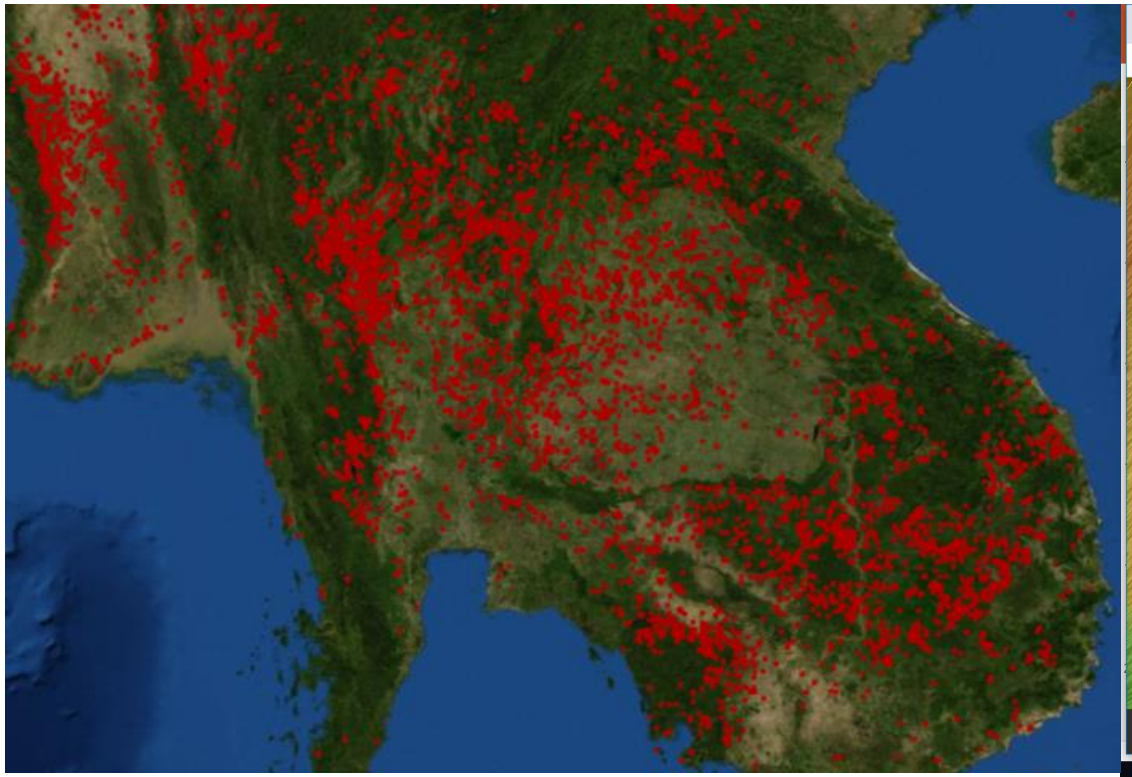
Determinants of Air Pollution

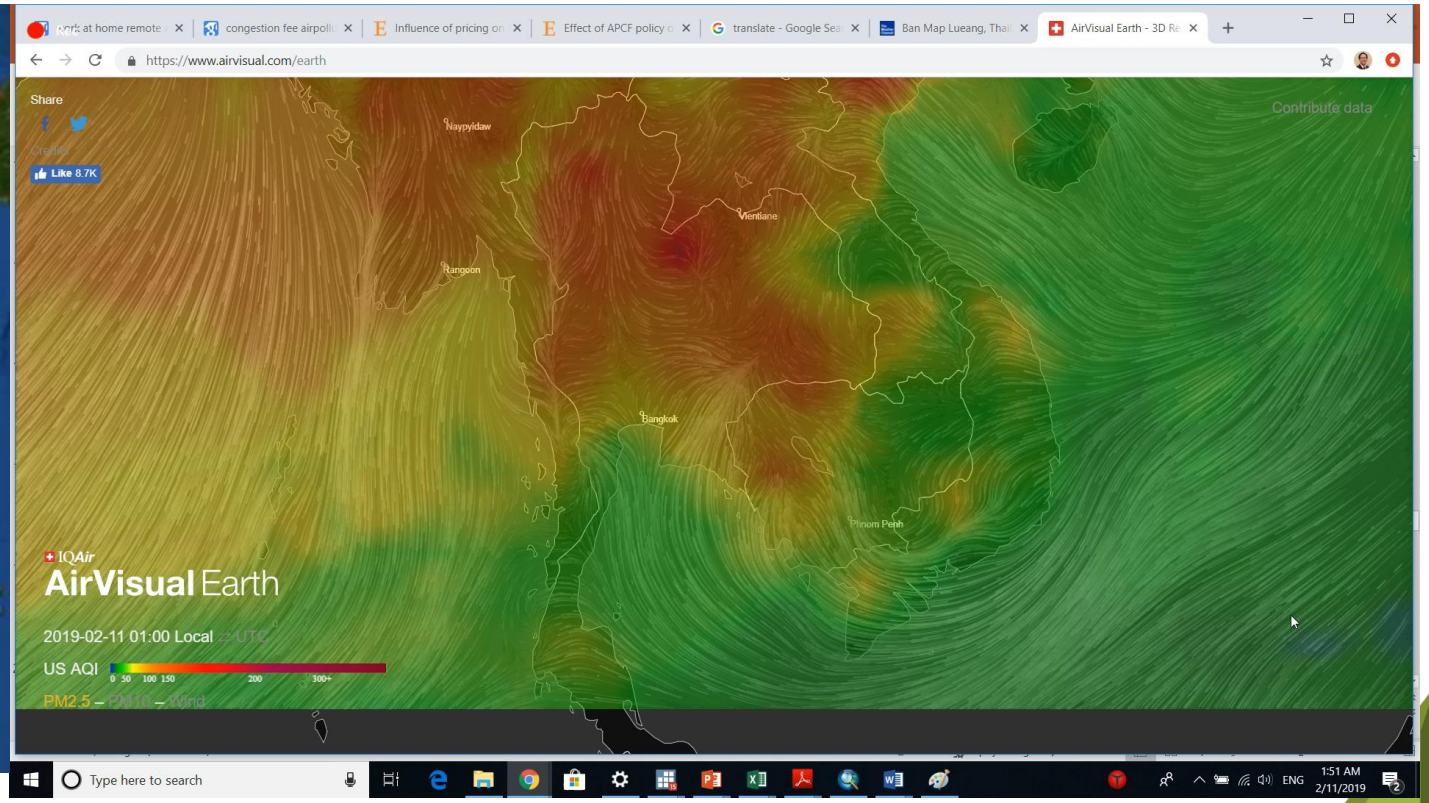
- **Domestic outdoor burning especially from agricultural residuals**
  - **Top three crops: Rice, sugarcane, and maize**



Determinants of Air Pollution

- **Transboundary pollution from burning agricultural residuals**
  - **Neighborhood countries (Laos, Cambodia, Myanmar)**





Valuing Air Quality Using Life Satisfaction Data

- This study employed the subjective well-being (SWB) approach to quantify the economic impacts of air pollution
- In the SWB approach, a household's life satisfaction was estimated as a function of income, environment and other covariates
- The SWB approach was introduced to address some weaknesses of traditional approaches
  - Address strategic biases and framing problems
  - A perfectly competitive market assumption is not assumed in the SWB method
  - Travel-cost and many hedonic models may underestimate the value of air quality since people most averse to air pollution choose to visit and live in cleaner places

Valuing Air Quality Using Life Satisfaction Data

- This approach has been previously used widely to value air quality (*e.g.*, Welsch, 2002, 2006; Luechinger, 2009; Levinson, 2012; Zhang, Zhang, and Chen, 2017; Laffan, 2018; Zheng et al., 2019)
- The main specification is

$$H_{ij} = \alpha P_{\text{ij}} + \gamma \ln Y_{ij} + \mathbf{X}'_{ij}\boldsymbol{\beta} + \varepsilon_{ij}$$

- H_{ij} is happiness score of household i^{th} in province j^{th}
- lnY_{ij} is income (in log form) of household i^{th} in province j^{th}
- $\mathbf{X_t}$ is a vector of covariates

Valuing Air Quality Using Life Satisfaction Data

- The previous equation is estimated using several techniques with different specifications
  - OLS with/without an instrumental variable
  - Ordered probit with/without an instrumental variable
  - Following Luttmer (2005), this study instruments for household incomes using the respondents' occupation
    - Whether respondents work in occupations with high wages

Valuing Air Quality Using Life Satisfaction Data

- The estimated marginal willingness to pay (WTP) for each pollutant was then estimated as follow:

$$\left.\frac{\partial Y}{\partial P}\right|_{dH=0} = -\frac{\hat{\alpha}}{\hat{\gamma}}\bar{Y}$$

- The main source of data was taken from 2012 life satisfaction survey, which collected 54,100 samples distributed throughout all provinces of Thailand.
- The provincial-level air quality and weather data were collected from Pollution Control Department

Economic Effects

Variable	Mean	Std. Dev.
Life satisfaction	7.7206	1.3109
Household characteristics		
Male	0.4694	0.4991
Age 15-19	0.0684	0.2525
Age 20-29	0.1414	0.3484
Age 30-39	0.2072	0.4053
Age 40-49	0.2343	0.4235
Age 50-59	0.2072	0.4053
*Age $\geq$ 60**	0.1416	0.3487
*Single**	0.1982	0.3986
Married	0.6950	0.4604
Divorce	0.1069	0.3089
Thai	0.9961	0.0623
Bachalor	0.1083	0.3108
Employed	0.1202	0.3252

Variable	Mean	Std. Dev.
Good health	0.6118	0.4873
Fair to bad health	0.3796	0.4853
Very bad health	0.0086	0.0922
No. household members	3.7263	1.6030
Municipal	0.3641	0.4812
Annual household income	4,679.1002	4,910.2405
Pollutants		
PM_{10} ($\mu g/m^3$)	37.3926	10.7338
NO_2 (ppb)	12.9685	4.7932
O_3 (ppb)	20.2253	3.9496
CO (ppm)	0.6014	0.1872
SO_2 (ppb)	2.7502	2.7805
Weather conditions		
Temperature (°C)	26.8643	0.9425
Rainfall (mm.)	164.5005	66.9597

Economic Effects

VARIABLES	Lifesatis PM10	Lifesatis SO2	Lifesatis NO2	Lifesatis CO	Lifesatis O3
ln (annual hh income)	0.192***	0.192***	0.192***	0.192***	0.192***
	(0.00660)	(0.00660)	(0.00660)	(0.00660)	(0.00660)
pollutant	-0.00203***	-0.00672*	-0.00336**	-0.261***	-0.00228
	(0.000467)	(0.00405)	(0.00133)	(0.0318)	(0.00152)
male	-0.0318***	-0.0315***	-0.0314***	-0.0311***	-0.0315***
	(0.00907)	(0.00907)	(0.00907)	(0.00907)	(0.00907)
age 15-19	-0.184***	-0.184***	-0.185***	-0.188***	-0.184***
	(0.0271)	(0.0271)	(0.0271)	(0.0271)	(0.0271)
age 20-29	-0.315***	-0.314***	-0.315***	-0.318***	-0.314***
	(0.0212)	(0.0212)	(0.0212)	(0.0212)	(0.0212)
age 30-39	-0.284***	-0.283***	-0.284***	-0.286***	-0.283***
	(0.0188)	(0.0188)	(0.0188)	(0.0188)	(0.0188)
age 40-49	-0.222***	-0.221***	-0.222***	-0.223***	-0.221***
	(0.0181)	(0.0181)	(0.0181)	(0.0181)	(0.0181)
age 50-59	-0.0856***	-0.0851***	-0.0856***	-0.0867***	-0.0851***
	(0.0176)	(0.0176)	(0.0176)	(0.0176)	(0.0176)

Economic Effects

VARIABLES	Lifesatis PM10	Lifesatis SO2	Lifesatis NO2	Lifesatis CO	Lifesatis O3
married	0.00235	0.00234	0.00229	0.00207	0.00305
	(0.0149)	(0.0149)	(0.0149)	(0.0149)	(0.0149)
divorce	-0.150***	-0.151***	-0.150***	-0.151***	-0.150***
	(0.0215)	(0.0215)	(0.0215)	(0.0215)	(0.0215)
thai	0.315***	0.316***	0.317***	0.318***	0.314***
	(0.0724)	(0.0721)	(0.0722)	(0.0722)	(0.0721)
bachalor	0.251***	0.251***	0.251***	0.253***	0.251***
	(0.0151)	(0.0151)	(0.0151)	(0.0151)	(0.0151)
employed	0.0159	0.0154	0.0159	0.0158	0.0153
	(0.0163)	(0.0163)	(0.0163)	(0.0163)	(0.0163)
fair to bad health	-0.332***	-0.333***	-0.332***	-0.333***	-0.333***
	(0.0102)	(0.0102)	(0.0102)	(0.0102)	(0.0102)
very bad health	-0.606***	-0.605***	-0.606***	-0.605***	-0.605***
	(0.0626)	(0.0627)	(0.0626)	(0.0627)	(0.0627)

Economic Effects

VARIABLES	Lifesatis PM10	Lifesatis SO2	Lifesatis NO2	Lifesatis CO	Lifesatis O3
no. hh members	0.0142***	0.0137***	0.0139***	0.0138***	0.0137***
	(0.00308)	(0.00308)	(0.00308)	(0.00308)	(0.00308)
municipal	-0.0493***	-0.0480***	-0.0474***	-0.0479***	-0.0479***
	(0.00964)	(0.00964)	(0.00963)	(0.00964)	(0.00964)
temperature (°C)	-0.141***	-0.140***	-0.137***	-0.124***	-0.140***
	(0.00793)	(0.00808)	(0.00822)	(0.00831)	(0.00811)
rainfall (mm.)	0.000667***	0.000729***	0.000708***	0.000710***	0.000731***
	(7.97e-05)	(7.82e-05)	(7.92e-05)	(7.83e-05)	(7.83e-05)
Central	0.147***	0.160***	0.133***	0.140***	0.167***
	(0.0395)	(0.0398)	(0.0402)	(0.0395)	(0.0408)
North	-0.00373	0.0102	-0.00596	-0.00551	0.0234
	(0.0455)	(0.0453)	(0.0459)	(0.0452)	(0.0456)
Northeast	0.135***	0.144***	0.149***	0.193***	0.153***
	(0.0455)	(0.0454)	(0.0454)	(0.0458)	(0.0455)
South	0.139***	0.152***	0.126***	0.100**	0.160***
	(0.0419)	(0.0417)	(0.0434)	(0.0421)	(0.0416)

Economic Effects

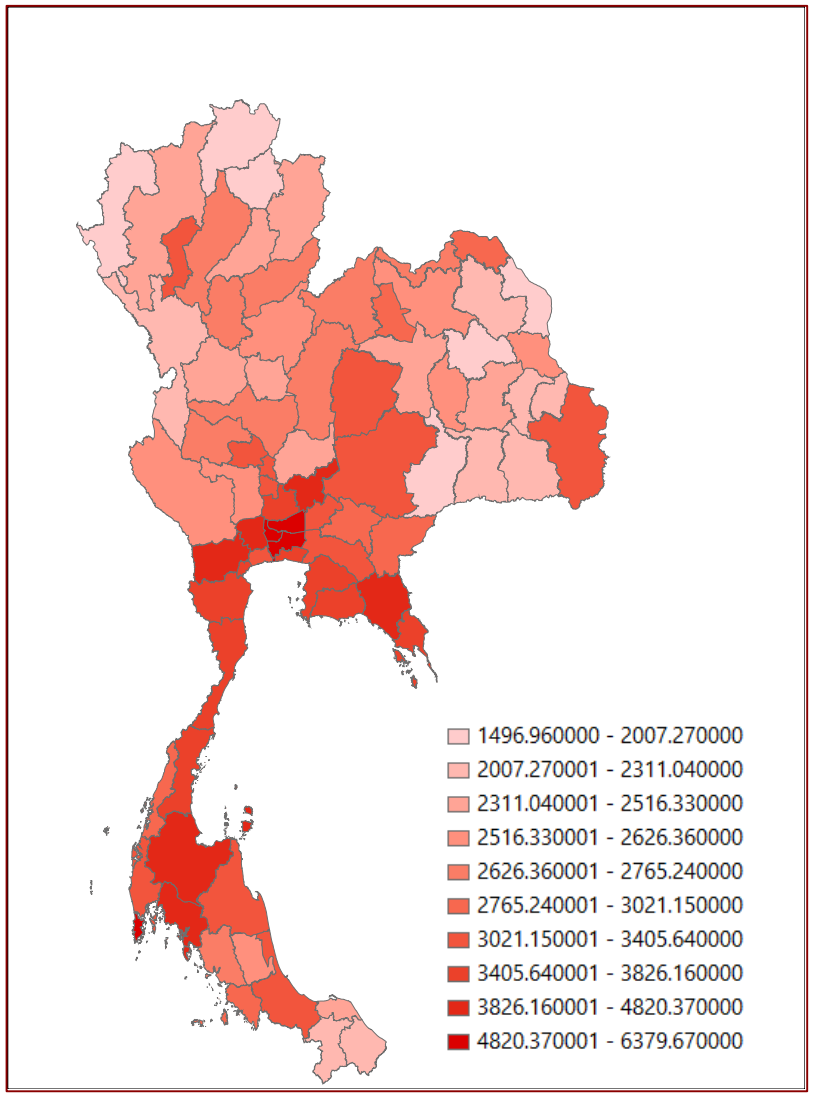
WTP (Baht/household/year) in Bangkok/unit of pollutant

Specifications	Willingness to Pay				
	SO_2	NO_2	CO	O_3	PM_{10}
OLS with	21,515.61*	11,142.06***	724,878.99***	7,497.89*	6,235.75***
lnincome	11,432.19	3,744.67	92,919.83	4,201.02	1,346.69
Ordered probit	19,186.81*	9,583.78**	746,246.44***	6,520.08	6,379.67***
with lnincome	11,611.98	3,819.10	95,372.32	4,350	1,312.40
WTP (Baht/	19,186.81-	9,583.78 -	724,878.99-		6,235.75-
Unit of pollutant)	21,515.61	11,142.06	746,246.44		6,379.67

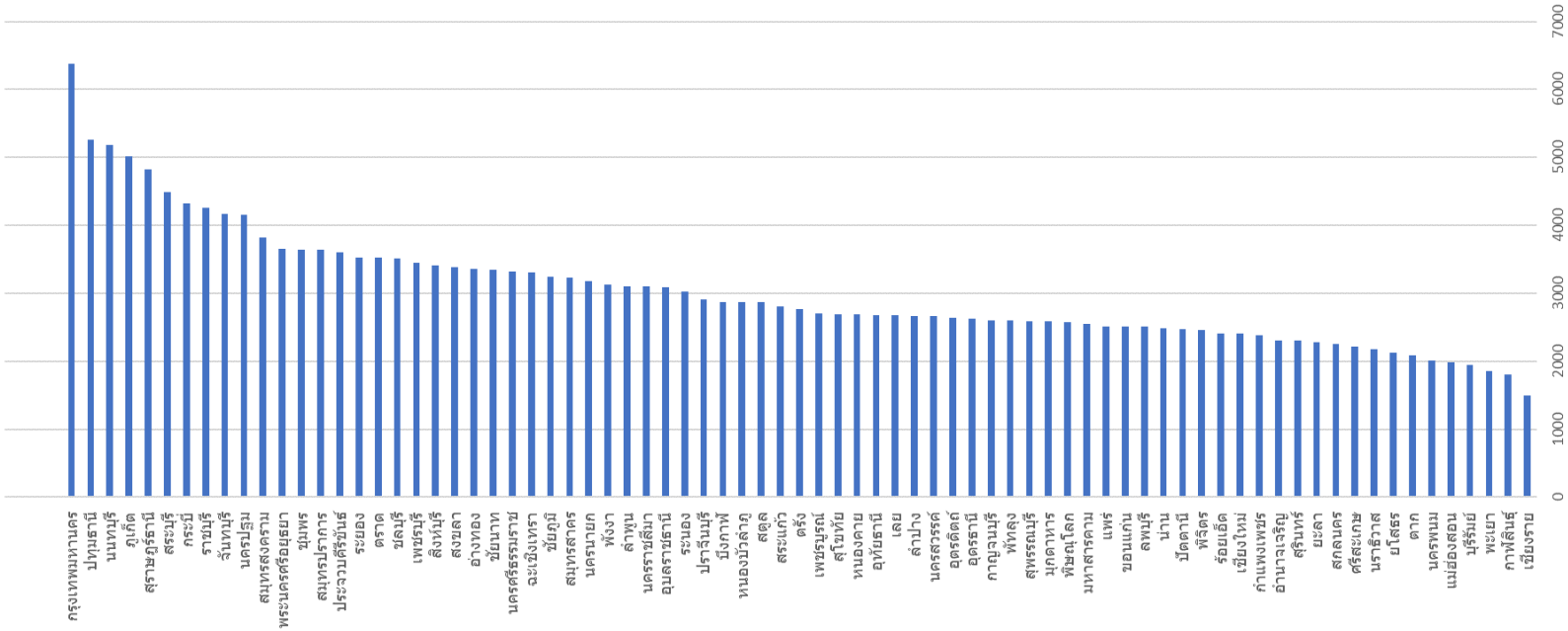
Economic cost of air pollution in Bangkok (Million baht/year/unit of pollutant)

Specifications	Willingness to Pay				
	SO_2	NO_2	CO	O_3	PM_{10}
OLS with	62,121.45*	32,170.18***	2,092,924***	21,648.48*	18,004.32***
lnincome	33,008	10,812	268,285	12,129	3,888
Ordered probit	55,397.57*	27,671 **	2,154,618***	18,825.30	18,419.86***
with lnincome	33,527	11,027	275,366	12,559.7	3,789
WTP (Baht/	2,064,919 -	1,031,424 -	78,012,770 -		18,004.32-
Unit of pollutant)	2,315,548	1,199,128	80,312,370		18,419.86

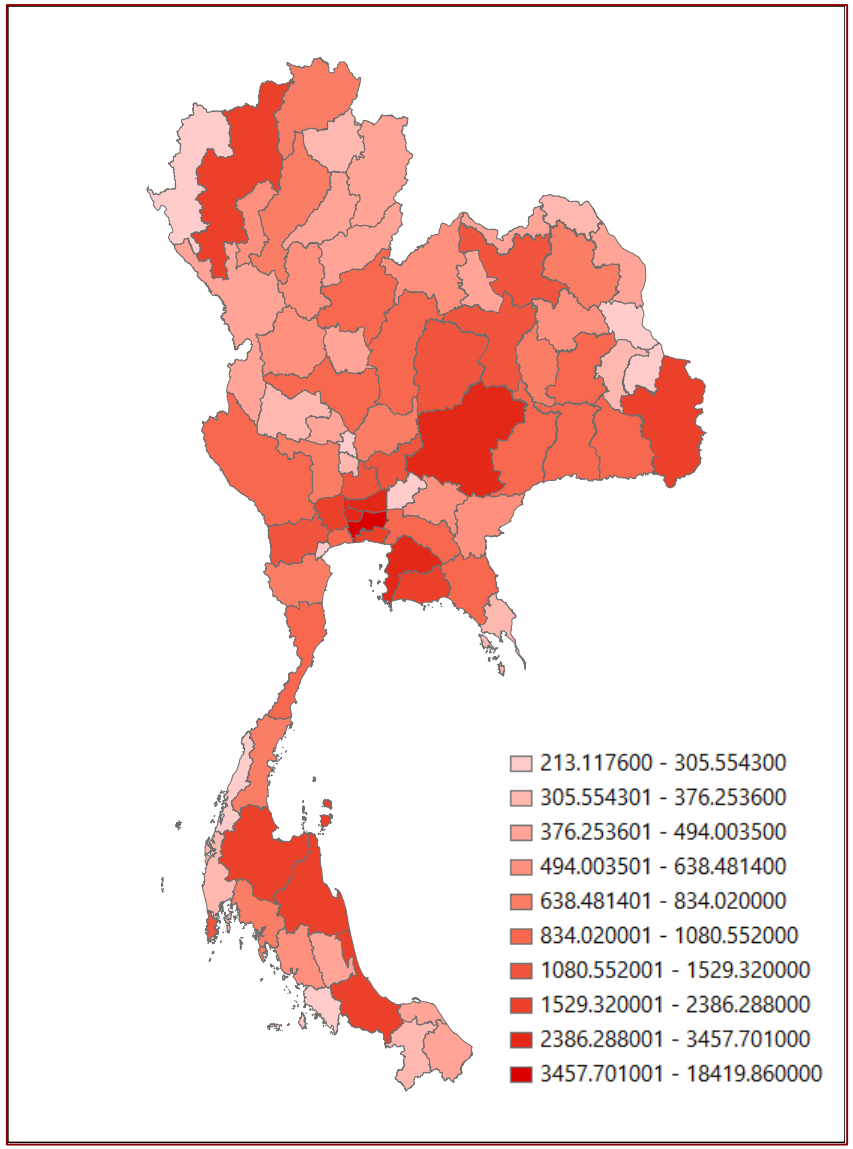
Economic Effects



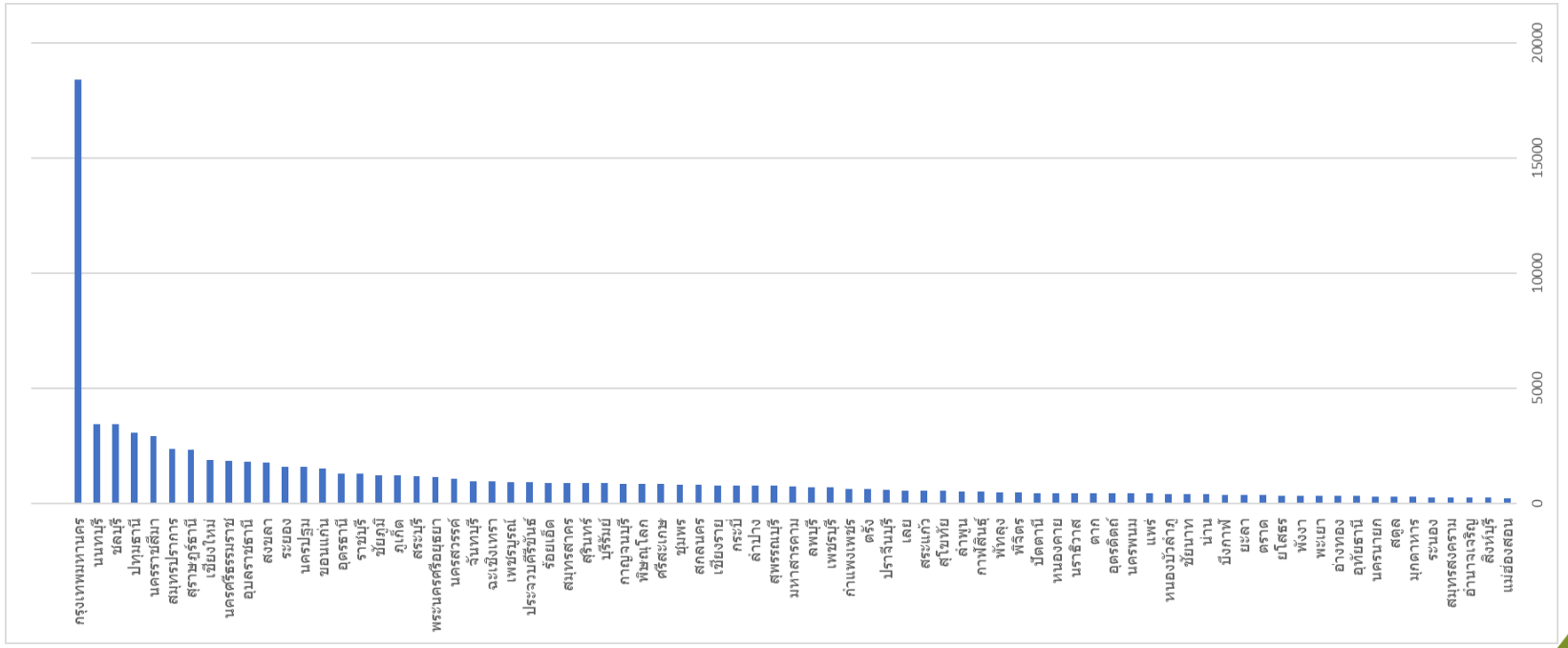
Provincial WTP to Reduce PM10
(Baht/household/year/ microgram/cubic meter)



Economic Effects



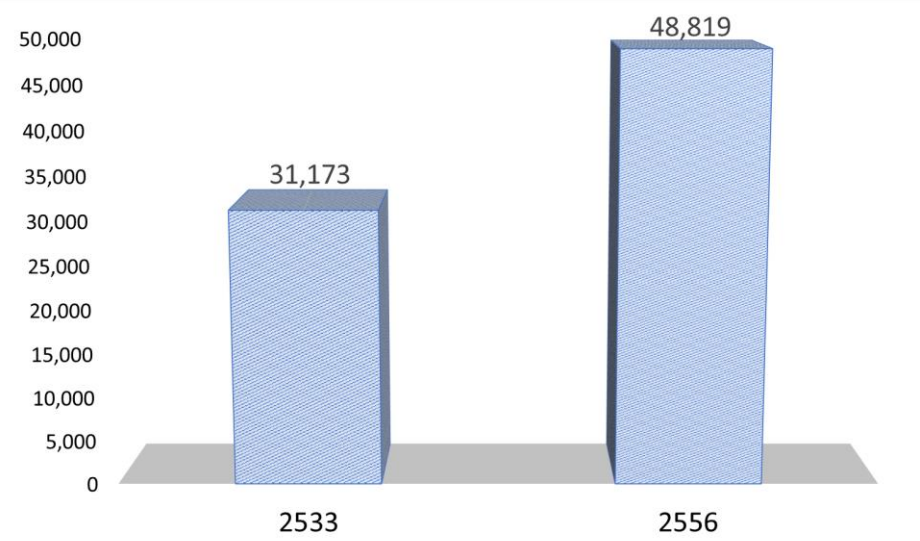
Provincial WTP to Reduce PM10
(Million Baht/year/microgram/cubic meter)



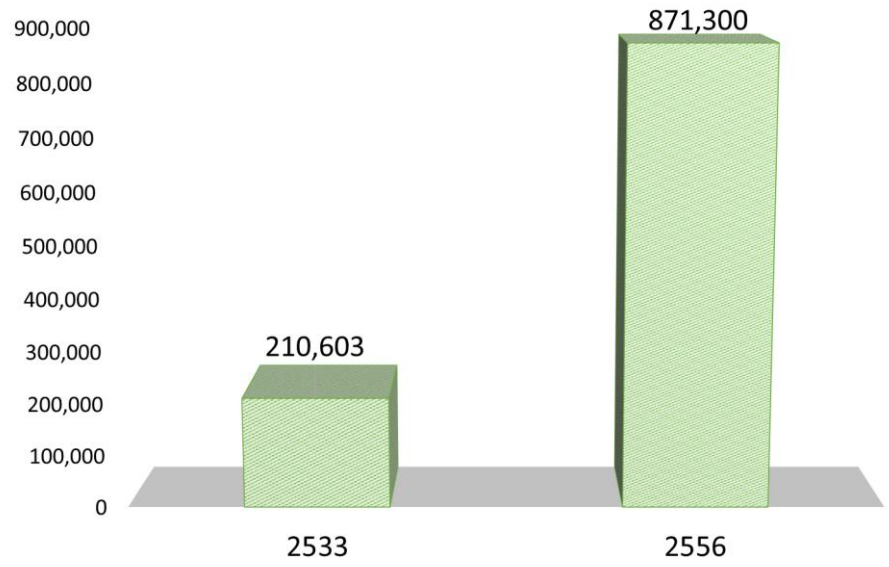
Economic Effects

- The findings are consistent with previous studies (*e.g.*, Levinson, 2012)
  - WTP in developed countries is higher than in that in developing countries
- In the U.S.A., Levinson (2012) reported that the WTP values for PM10, O3, and SO2, were $728 per μg/m3, $286 per ppb, and $330 per ppb, respectively
- World Bank & Institute for Health Metrics and Evaluation (2016) found that

Total deaths from air pollution (Person)



Total welfare losses (Million Baht)



Policy Recommendations

- Tools in Economics
  - Control behaviors: Incentives vs. command and control
  - Level of controls: Direct or Indirect
  - Control variables: Price, quantity, or technology
- Recommended Measures (Short-Medium-Long Run)
  - Create awareness of the dangers of toxic dust (Silent Killer)
    - S: Create awareness to everyone including policy makers & private sector
    - S: Add air quality monitoring points
    - M: Promote research to assess the impact of toxic dust on health
    - M: Create awareness of the dangers of air pollution to children
    - M-L: Increase air quality standards in all pollutants

Policy Recommendations

- Recommended Measures (Short–Medium–Long run)
  - Reduce burning fossil fuels of cars
    - S: Strict black smoke monitoring, engine modification and renew car registration
    - S-M: Limit the amount of cars in the city area with traffic congestion
    - M: Increase the efficiency of public transportation systems
    - M: Improve the plan and management of transportation and traffic
    - M: Collect additional taxes for cars that have been in use for many years
    - M-L: Move to EURO 5-6 standards for oil and vehicles
    - M-L: Promote and prepare for the use of electric vehicles (EV)

Policy Recommendations

- Recommended Measures (Short–Medium–Long run)
  - Reduce burning fossil fuels and toxic materials from factories
    - S: Strict monitoring emissions
    - M: Accelerate the promotion and upgrading of environmentally friendly production
    - L: Promote clean energy technologies for production
  - Reduce outdoor burning especially burning agricultural residuals

    Domestic
    - S: Requesting cooperation from farmers and private sector who buy agricultural products
    - S: Raise awareness for farmers
    - S: Ban outdoor burning in all locations during Dec-Feb in every year
    - M: Encourage farmers to use agricultural residues to make compost
    - M-L: Create markets for agricultural residuals: Feed for livestock and power plant

Policy Recommendations

- Recommended Measures (Short–Medium–Long run)
  - Reduce outdoor burning especially burning agricultural residuals

    International
    - S: Request cooperation and create mutual agreements with neighboring countries plus provide some financial supports to expedite the outcome
    - M: Prepare to study and implement gradual trade barriers if there is no cooperation
- Draft and implement the Clean Air Act for Thailand
  - Isen et al. (JPE: 2017) find a significant relationship between pollution exposure in the year of birth and later life outcomes
    - A higher pollution level in the year of birth is associated with lower labor force participation and lower earnings

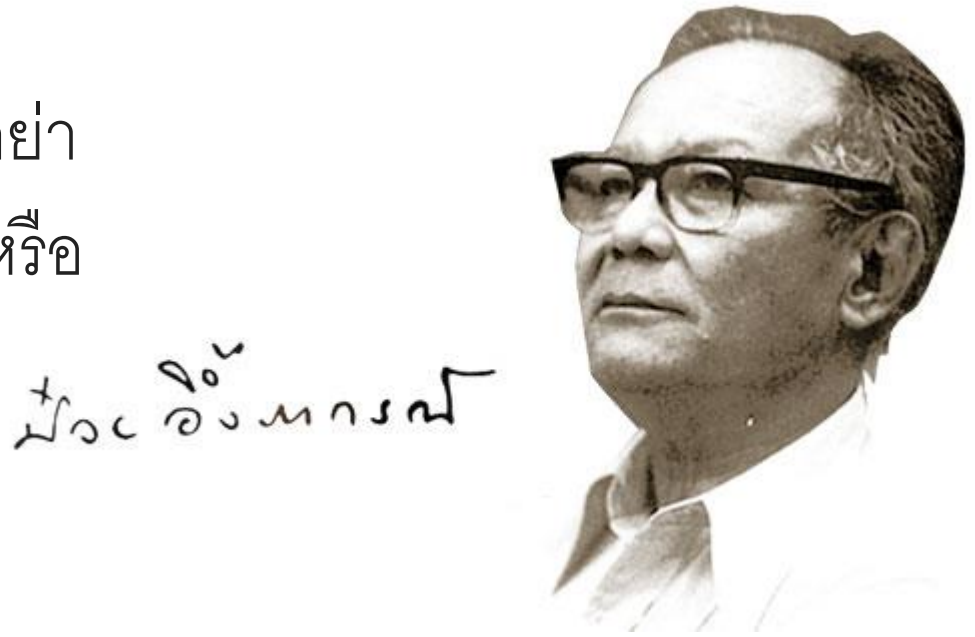
Policy Recommendations

- Draft and implement the Clean Air Act for Thailand
  - Isen et al. (JPE: 2017) find that a higher pollution level in the year of birth is associated with lower labor force participation and lower earnings
  - Chay & Greenstone (NBER: 2003) reveal that 1% decline in TSPs results in a 0.5% decline in the infant mortality rate
    - The results imply that roughly 1,300 fewer infants died in 1972 than would have in the absence of the Clean Air Act 1970
  - Bento, Freedman & Lang (RES: 2015) estimated that 1% increase in PM10 will cause house prices to fall by 0.6%
    - Lower income homeowners tended to enjoy the greatest benefits from the 1990 CAAA

Policy Recommendations

- Draft and implement the Clean Air Act for Thailand
  - Porter and van der Linde (JEP: 1995) proposed “Porter hypothesis”
    - Strict environmental regulations can induce efficiency and encourage innovations that help improve commercial competitiveness
    - Regulations should use incentive measures in stead of command and control to create innovation

“ผมต้องการอากาศบริสุทธิ์สำหรับหายใจ น้ำดื่มบริสุทธิ์สำหรับดื่ม ... เมื่อจะตาย ก็ขออย่าให้ตายอย่างโง่ๆ อย่างบ้าๆ ... ตายเพราะน้ำหรืออากาศเป็นพิษ”



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Q & A

Contact Information:
Witsanu Attavanich, Ph.D.
Associate Professor

Faculty of Economics, Kasetsart University
50 Phahonyothin Rd., Chatuchak,
Bangkok, Thailand, 10900
witsanu.a@ku.th
https://sites.google.com/site/attavanichw/

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