The Effect of Air Pollution on Infant Mortality in Mexico City

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joint with
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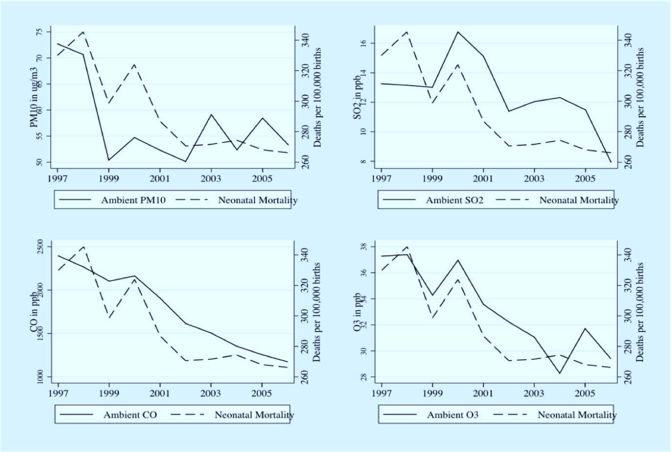
Motivation

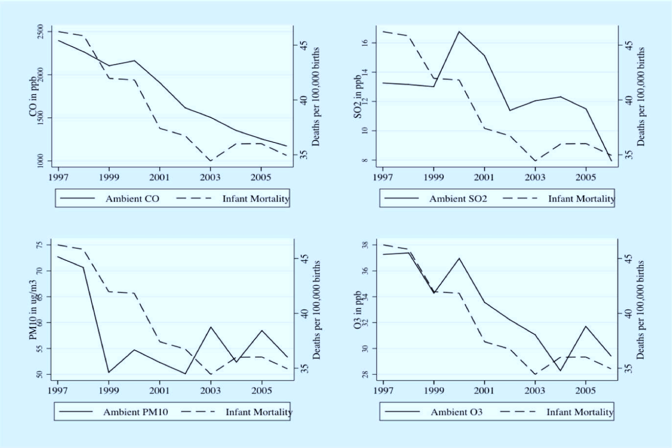
- Growing literature of the effect of air pollution on health in developed countries (Chay and Greenstone 2003, Currie and Neidell 2005, Moretti and Neidell 2011, Shlenker and Walker 2011)
- Limited literature on this relationship in the developing world (Jayachandran 2009, Chen, Ebenstein, Greenstone and Li 2012)

Neonatal Mortality and Pollution Trends



Infant Mortality and Pollution Trends

Can short-term air pollution effects explain the falling trends in infant mortality of the last 10 years?



What we ask

- What is the short-run effect of PM_{10} and CO on infant mortality in Mexico City?
- Does being at a different place of the pollution-mortality gradient matter?
- Can improvements in air quality explain some of the gains in infant health over the period we study?

What we do

- Estimate the short-run effects of air pollution on weekly neonatal and infant mortality rates in Mexico City

- Use thermal inversions, a meteorological phenomenon, as an instrument for air pollution

What we find

- 1 ug/m3 of PM10 leads to 12.85 more infant deaths per 100,000 (Chay and Greenstone's estimates are 7.1-15.1)
- 1 ppb of CO leds to 0.250 more infant deaths per 100,000 (Currie and Niedell's 2005 estimates are 0.016-0.034 in their single-pollutant models)
- Suggestive evidence of nonlinearities in CO
- Accounting for correlation between pollutants, we find that the reduction in pollution between 1997 and 2006 was responsible for at least

Outline of the Talk

1. Introduction
2. Background on Health-Pollution Link
3. Data and Research Strategy
4. Main Results
5. Robustness and Specification Checks
6. Conclusion and Future Work

Health Consequences of Air Pollution

Small and Fine Particulate Matter

- Respiratory symptoms
- Decreased lung function
- Nonfatal heart attacks
- Premature death among people with heart and lung disease

Health Consequences of Air Pollution

Carbon Monoxide

- Reduced oxygen delivery to body's organs
- At extremely high levels, CO can cause death (EPA)
- Among people with heart disease, it may cause myocardial ischemia during exercise (EPA)
- Recent studies found an association between CO and irregular heartbeat, which causes cardiovascular damage (INSP, 2011)

Data

Mexico City, 1996 – 2006 Infant Mortality Data:

- Daily data on infant deaths at municipality level (48 municipalities) from the Ministry of Health
- Infant deaths Includes data on gender of child, age, cause of death, and state and municipality of residence
- Data on births from birth certificates at the municipality data.
  - We aggregate it at the weekly level

Data

Pollution and Weather Measures

- Hourly station data from 32 stations: PM10, CO, SO2, O3
- Temperature, Cloud Cover, Precipitation, Humidity from stations and city level data
- Aggregate to Municipality-Weekly Level following Currie and Neidell (2005)

Econometric Model

OLS

$$Y_{mw} = \beta_0 + \beta_1 P_{mw} + f(T_{mw}) + \epsilon_{mw}$$

$Y_{mw} \equiv$ deaths per 100,000 births in municipality m and week w

$P_{mw} \equiv$ pollution conc in ug/m^3 or ppb

$f(T_{mw}) \equiv$ 4th deg polynomial in mean temperature, 3rd deg polynomial in min and max pollution, precip, cloud and humidity

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Econometric Model

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FE

$$Y_{mw} = \gamma_0 + \gamma_1 P_{mw} + f(T_{mw}) + \sigma_m + \sigma_w + \eta_{mw}$$

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IV

$$P_{mw} = \gamma_0 + \gamma_1 I_w + f(T_{mw}) + \theta_m + \psi_m w + \theta_y + u_{mw}$$
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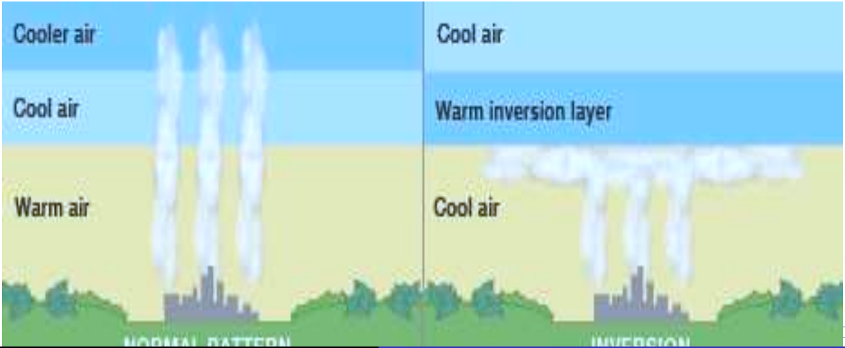
Thermal Inversions

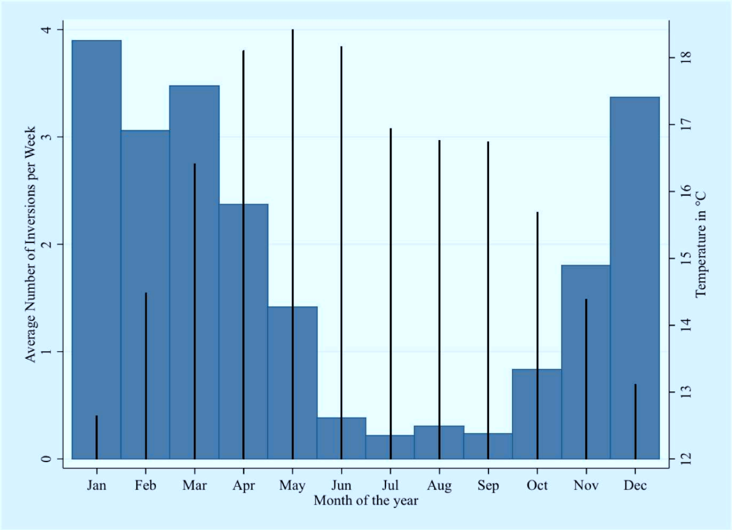
- Normally, temperature falls at at about 6°C per km
- However, sometimes you can find a mass of hot air on top of a mass of cold air: a **thermal inversion**
- Thermal inversions do not represent any health risk in itself
- However, emissions released can be trapped by the layer of warm air



Thermal Inversions

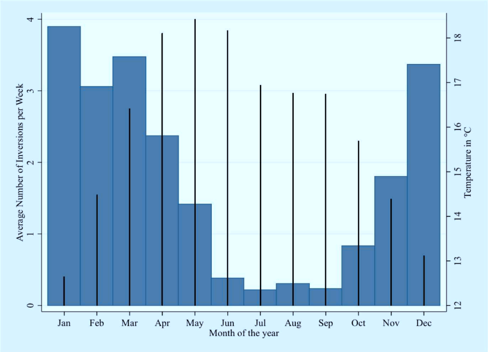
- Thermal inversions are recorded by the Metereological Unit of the local Ministry of Environment
- They register thermal inversions using aerostatic balloons that measure temperature at different altitudes
- In addition, they record time and temperature of rupture, thickness, etc
- Screenings are conducted every hour on almost every day

Thermal Inversions and Temperature

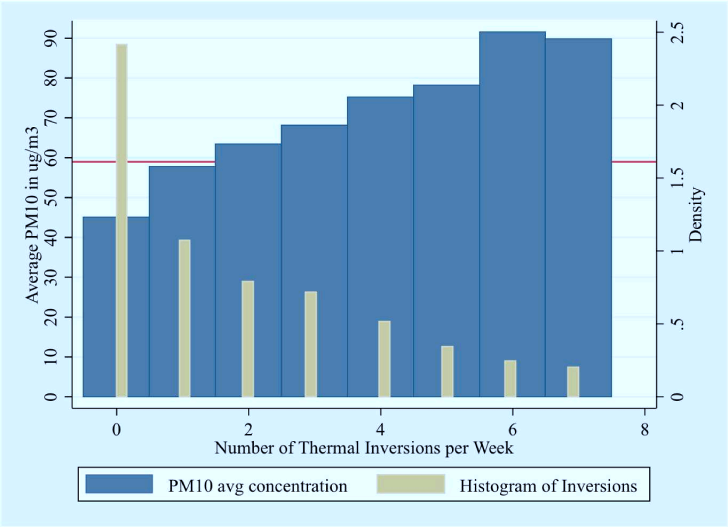


Thermal Inversions and Temperature

- Thermal inversions (bars) have the highest frequency in the winter
- Medium and high temperature months (spikes) have some inversions too

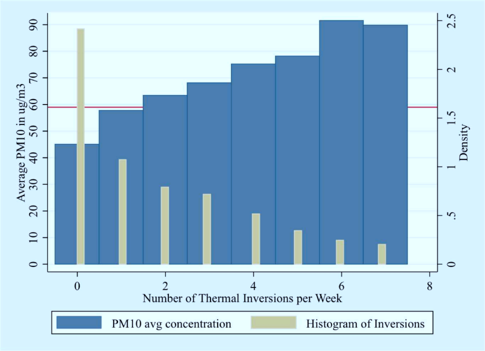


Thermal Inversions and Pollution: PM10

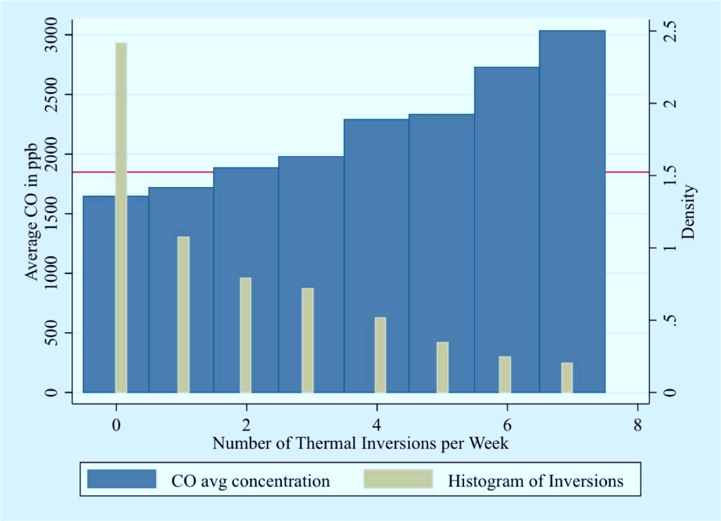


Thermal Inversions and Pollution: PM10

- Many weeks of the year have one or more thermal inversions
- Because of its high frequency, thermal inversions move pollution across its mean value (red line)



Thermal Inversions and Pollution: CO



Identification assumption in IV

Conditioning on ground-level temperature and other weather variables, thermal inversions are uncorrelated with infant mortality rates outside of the pollution channel

It will not hold if

- Lower visibility increases accidents
- Other seasonal effects, like flu, coincide with thermal inversions

Avoidance Behavior and Thermal Inversions

- Thermal inversions cause visible pollutants to congregate
- Individuals may react to visible pollution with avoidance behavior

Welfare estimation

- If individuals incurr additional costs to avoid exposure or counteract damages (e.g. medical expenditures, moving costs, etc.) impact of infant mortality underestimates welfare impact

Policy relevant effect

- Effect on individual's health after they react to policy (e.g., lower pollution)

Simple Correlations (OLS)

- All pollutants are positively correlated with infant mortality
- Correlations are robust to temp controls for PM10 and CO, but not for SO2 and O3

	Neonatal (1)	Infant (2)	Neonatal (3)	Infant (4)
Mean Pollution Concentration				
PM 10	0.617***	0.123***	0.883***	0.130***
	(0.119)	(0.019)	(0.156)	(0.019)
Sulfur Dioxide (SO_2)	0.671	0.434***	0.874*	0.052
	(0.499)	(0.068)	(0.522)	(0.061)
Carbon Monoxide (CO)	0.031***	0.007***	0.032***	0.004***
	(0.004)	(0.001)	(0.005)	(0.001)
Ozone (o3)	1.595***	-0.057	1.737***	0.188***
	(0.323)	(0.047)	(0.394)	(0.051)
Weather controls			X	X

First Stage for IV

- Strong positive relationships between thermal inversions and PM10, CO
- No relationship with O3
- Non-robust negative relationship with SO2

	Mean Pollution Concentrations			
Dependent Variable:	PM10	SO2	CO	O3
	(1)	(2)	(3)	(4)
Inversions	2.107***	-0.265**	104.759***	0.163
	(0.416)	(0.132)	(9.040)	(0.409)
Year FE	X	X	X	X
Municipality FE	X	X	X	X
Weather Controls	X	X	X	X
Municipality Specific Week Trends	X	X	X	X
Observations	18,409	18,544	18,538	18,537

FE and IV: PM10 and CO

Results for PM10 and CO

	Neonatal		Infant	
	FE	IV	FE	IV
	(1)	(2)	(3)	(4)
Mean Pollution Concentration				
PM 10	0.1786	0.4665	0.0351	0.2471**
	(0.3028)	(0.9561)	(0.0308)	(0.1194)
Carbon Monoxide (CO)	0.0138	0.0095	-0.0002	0.0049**
	(0.0121)	(0.0190)	(0.0014)	(0.0021)
Mean Mortality Rate	295.83	295.83	38.21	38.21
Instrument: Inversions		X		X
Week FE	X		X	
Year FE		X		X
Municipality FE	X	X	X	X
Weather Controls	X	X	X	X
Municipality Specific Week Trends	X	X	X	X

Robustness checks

Potential violations of the exclusion restriction

- Low visibility => more accidents
- Inversions pick up seasonal effects on mortality
- Weather and temperature controls

Specification checks

- Log-mortality model
- Lagged and cumulative pollution
- Multiple pollutants
- Nonlinearities

Accidents or Illness?

- External = homicides and accidents; Internal=1-External
- RCDC = respiratory, cardiovascular, digestive and congenital

Neonatal Mortality

Dependent variable: Infant Mortality by Cause	Neonatal			
	External	Internal	Non-RCDC	RCDC
	(1)	(2)	(3)	(4)
PM10	-0.022 (0.071)	0.042 (0.678)	-0.293 (0.669)	0.313*** (0.115)
CO	-0.000 (0.001)	0.001 (0.014)	-0.006 (0.013)	0.007*** (0.002)
Mean Mortality Rate	3.27	287.73	283.15	7.85
Municipality FE	X	X	X	X
Year FE	X	X	X	X
Weather Controls	X	X	X	X
Municipality Specific Time Trend	X	X	X	X

Accidents or Illness?

- External = homicides and accidents
- RCDC = respiratory, cardiovascular, digestive and congenital

Infant Mortality

	Infant			
Dependent variable: Infant Mortality by Cause	External	Internal	Non-RCDC	RCDC
	(5)	(6)	(7)	(8)
PM10	0.016	0.186*	0.078	0.124***
	(0.013)	(0.095)	(0.069)	(0.046)
CO	0.000	0.004**	0.002	0.003***
	(0.000)	(0.002)	(0.001)	(0.001)
Mean Mortality Rate	1.18	36.52	30.79	6.91
Municipality FE	X	X	X	X
Year FE	X	X	X	X
Weather Controls	X	X	X	X
Municipality Specific Time Trend	X	X	X	X

Seasonal Effects

- Results robust to season dummies instead of year dummies
- Seasons + Year Dummies do not change coefficient, although we lose significance
- Inversions are positively correlated with infant mortality in Summer and Winter

Specification Checks

Lagged and Cumulative Pollution

- About 4,000 observations with missing lagged pollution
- In restricted sample, effect of PM10 and CO is non-significant, but doesn't change with lag
- Controlling for cumulative pollution (average pollution per week since utero) does not change our coefficients

Log-Deaths as Dependent Variable

- Denominator in main specification is births, not live infants
- Gives more importance to older babies
- Log-deaths specification yields 40% smaller effects, but still significant at 10% level

One instrument, two pollutants

- We cannot interpret the effects of PM10 and CO as independent
- If PM10 and CO are highly correlated, the two effects estimated might be "double counting" deaths

- One approach: more instruments
- Another approach: Pollution Index

Multiple Pollutant Model: First Stage

Use interactions with

- Altitude at each municipality
- Thickness of the inversion layer

	PM10 (1)	CO (2)
Inversions	11.2243*** (1.7686)	95.777*** (29.002)
Inversions * Altitude	-0.00470*** (0.00081)	-0.00052 (0.01466)
Thickness * Altitude	0.000018*** (0.000007)	0.00032** (0.00016)
Angrist-Pischke F-statistic	15.99	43.54

Multiple Pollutant Models

- Column (1) shows the results of two multiple pollutant models
- Columns (2) and (3) show a back of the envelope calculation of lives saved per year for the reduction in pollution between 1997 and 2006

	Infant (1)	Change in Pollution (2)	Change in Deaths per year (3)
Panel A: IV Model with PM10 and CO			
Mean Pollution Concentration			
PM 10	0.0356	-17.51	-91.3
	(0.2243)		
Carbon Monoxide (CO)	0.0041	-1171.10	-703.3
	(0.0052)		
Panel B: Principal Components Index for PM10 and CO			
Pollution Index	2.6430**	-1.99	-768.5
	(1.1668)		

Nonlinearities in PM10

Is there evidence of nonlinearities in the short-run effect of PM10?

- Coefficients look similar for effect of PM10 on infant mortality, but...
- First stage has low power for low PM10 concentrations

	Neonatal (1)	Infant (2)
PM 10 between 0 and 50 ug/m^3	0.4710	0.2938
	(2.3727)	(0.2823)
PM 10 between 50 and 300 ug/m^3	1.6457	0.3363**
	(1.2362)	(0.1503)
Angrist-Pischke F-statistic, First Stage 1	7.521	7.606
Angrist-Pischke F-statistic, First Stage 2	12.51	11.85
Equal Slopes F (Chi-squared) Statistic	0.238	0.0224
p-value	0.626	0.881

Nonlinearities in CO

Can nonlinearities explain the difference between our results and Currie and Neidell's results?

- Coefficient for infant mortality much smaller in the 0-2100 range than in the 2100-3000 range
- First stage is better identified
- Non-significant difference in slopes

	Neonatal (1)	Infant (2)
CO between 0 and 2100 ppb	-0.0179	0.0009
	(0.0432)	(0.0046)
CO between 2100 and 3000 ppb	0.0717	0.0114*
	(0.0575)	(0.0064)
Angrist-Pischke F-statistic, First Stage 1	14.61	14.54
Angrist-Pischke F-statistic, First Stage 2	15.32	15.01
Equal Slopes F (Chi-squared) Statistic	0.960	1.098
p-value	0.327	0.295

Conclusion

- Findings
  - 1 ug/m3 of PM10 results in 12.85 lost lives per 100,000 births
  - 1 ppb of CO results in 0.250 lost lives per 100,000 births
  - multiple pollutant models suggest that the pollution reductions in the 1997-2006 period amounted to

    789 lives saved per year[1]
- IV estimates using thermal inversions as an instrument are similar in magnitude to Chay and Greenstone TSP estimates, but much larger than Neidell and Currie CO estimates
  - Suggestive evidence of nonlinearities in CO
  - No evidence of nonlinearities in PM10

[1] There were 281,682 births per year in average between 1997-2006 in the area covered by our study. This calculation only accounts for deaths among babies that are less than one year old.

Future Work

- More on whether IV-FE differences are due to measurement error or differences between ATE and LATE
- Fetal deaths
- Is neonatal death lower than infant due to the fact that small babies are more likely to stay inside on bad pollution days?
  - Use pollution announcements

Extra Slides

Mexico - US comparisons: Infant Mortality

- Infant mortality rate is close to three times the US national rate

	Mexico 1997-2006 (1)	U.S. 1997-2006 (2)	CA 1989-2000 (3)
Deaths per 100,000			
Infant, 28 days	1159.72	460	
Infant, 1 year	1964.85	698	391.00
Child, 5 years	2539.50		

Mexican and US data: Pollution Levels

- Pollution much higher than in CA
- Similar magnitude than US national level concentrations (are measures comparable?)

	Unit	MCMA 1997-2006 (1)	Unit	MCMA 1997-2006 (2)	U.S. 1997-2006 (3)	CA, U.S. 1989-2000 (4)
Particulate Matter (PM10)	*avg µg/m3*	58.19	*avg µg/m3*	58.19	62.17	39.13
Sulfur Dioxide (SO_2)	*avg ppb*	14.13	*avg ppb*	14.13	4.476	
Carbon Monoxide (CO)	*avg ppb*	1888.75	*8hr ppb*	3439.00	3281.20	1975.00
Ozone (O_3)	*avg ppb*	32.43	*8hr ppb*	63.53	82.20	40.42
Inversions	*# per week*	1.68				

FE and IV: SO_2 and O_3

	Neonatal		Infant	
	FE	IV	FE	IV
	(1)	(2)	(3)	(4)
Sulfur Dioxide (SO_2)	1.6329	-3.7026	0.1098	-2.1814
	(1.0998)	(8.5958)	(0.1078)	(1.4916)
Ozone (o3)	0.8032	2.4085	0.1401	3.3567
	(1.1334)	-12.9578	(0.1085)	(4.1997)
Mean Mortality Rate	295.83	295.83	38.21	38.21
Instrument: Inversions		X		X
Week FE	X		X	
Year FE		X		X
Municipality FE	X	X	X	X
Weather Controls	X	X	X	X
Municipality Specific Week Trends	X	X	X	X