Can Light Rails Provide the Track to Cleaner Air?

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Why Light Rail?

- Light rail is a form of rail public transit with trains that combine features from buses and subways.
- Compared to buses:
  - Higher capacity, more frequent operation
  - Lower maintenance
  - Can have exclusive right-of-way
- Compared to subways:
  - Cheaper to construct a new system (no tunnels needed!)
  - Can reach more residents and stop at more locations

Data: Light Rail Routes

- We focus on light rail systems in our study opened after the 2000s (our PM2.5 dataset has data from 2000 to 2016).
- We picked systems in cities where light rail was the primary mode of rail transit, allowing us to isolate air pollution effects resulting from the opening of a light rail.
- Cities with a population of at least 1 million residents were picked to ensure light rails were in urban cities.
- After considering these criteria, our panel of cities was narrowed down to two systems:

  Charlotte, NC's LYNX system and Phoenix, AZ's Valley Metro Rail system.

Literature Review

- Previous studies on the air pollution impact of public transit (Chen and Whalley, 2012; Gendron-Carrier et al., 2022; Xie et al., 2024) used Discontinuity-Based OLS as there was instant uptake in ridership.

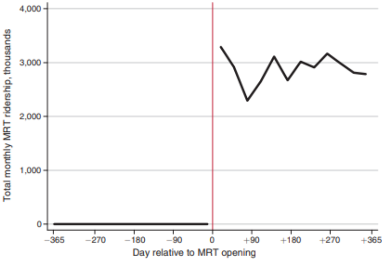
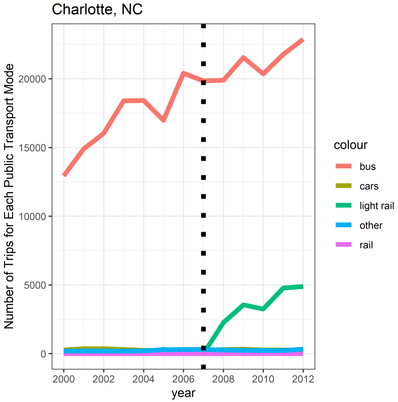
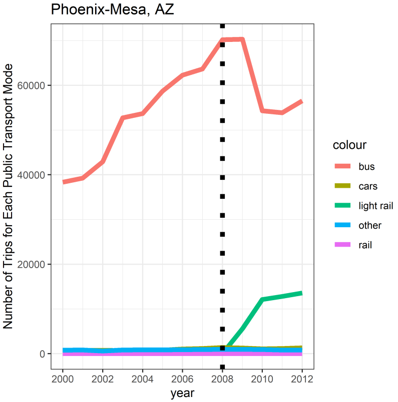


FIGURE 1. RIDERSHIP ON THE TAIPEI METRO

Figure 1: Ridership Data from Chen and Whalley (2012)

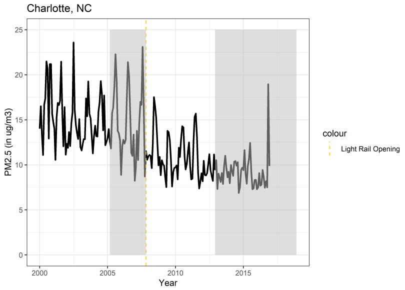
Literature Review

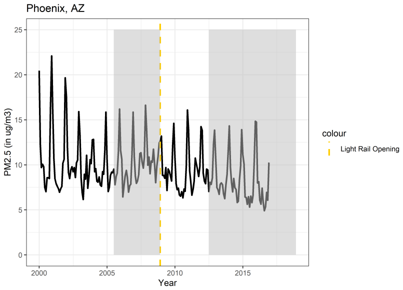




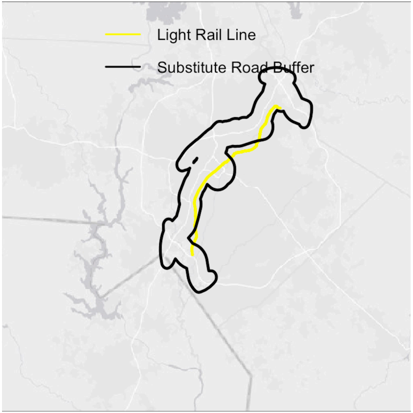
Literature Review

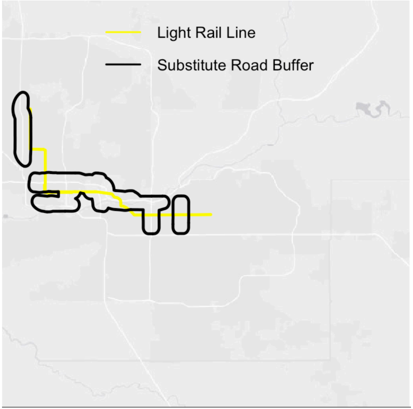
- *Fageda, 2021* used DiD to estimate the impact of light rail openings across 98 European cities, and found that air pollution was reduced by 3 percent.
- They study used annual PM2.5 data, going back only up to 3 years before opening, which can confound with construction time.





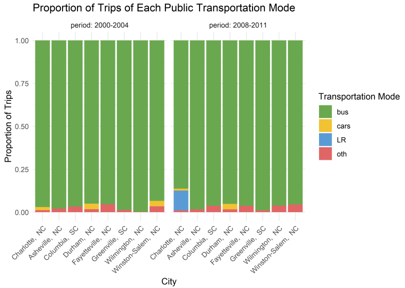
Treated Area

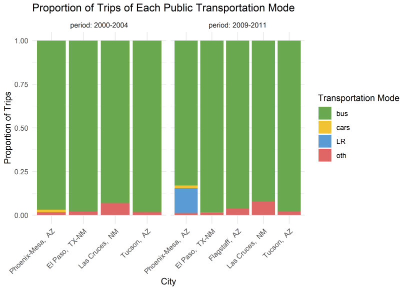




Untreated Area

For each control city, we find cities with no light rails, no subways, and similar public transportation profiles.

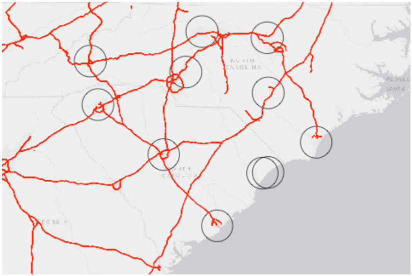




Untreated Area

- For each untreated city, we draw a 30 km radius around each city's centroid, crop interstates segments that fall within that centroid, and draw 1 km radius around each cropped interstate.
- We then find the daily average PM2.5 levels within each 1 km radius around the cropped interstate area for each city.

Treated Area in Charlotte, NC



DiD Methodology

For each treatment city, we use data from untreated city with similar public pre-light-rail transportation profiles as controls. Our main regression specification is:

$$P_{it} = \gamma(D_i \times Open_t) + W'_{it}\beta + \mu_{it} + \epsilon it$$

where P_{it} are PM2.5 levels (in ug/m3) for each city i and day t.

D_i is a dummy variable that is equal to one when city i is the city with a light rail system.

$Open_t$ is a dummy variable that is equal to one when the light rail system in the treated city is in operation.

W_{it} includes 48 meteorological control variables in its linear, square, and cubic form for each city and day.

$\mu_i t$ are city-day of week-month-year fixed effects.

DiD Results

Table 1: DiD Results for Charlotte, NC

Dependent Variable:	pm25			
Model:	(1)	(2)	(3)	(4)
Variables				
operating × treatcity	-0.51	-0.54	-0.52	-0.57*
	(0.32)	(0.31)	(0.28)	(0.28)
Wind_f_tavg	-2.1***	-2.0***	-3.4***	-2.4***
	(0.54)	(0.52)	(0.53)	(0.54)
Wind_f_tavg_sq			0.42***	0.28**
			(0.11)	(0.12)
Wind_f_tavg_cu			-0.03**	-0.02
			(0.009)	(0.010)
Fixed-effects				
dow_m	Yes		Yes	
Address	Yes	Yes	Yes	Yes
dow_my		Yes		Yes
Fit statistics				
Observations	29,936	29,936	29,936	29,936
Adjusted R^2	0.32	0.42	0.33	0.43

Clustered (Address) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

DiD Results for Each Day of the Week

Table 2: DiD Results for Charlotte, NC

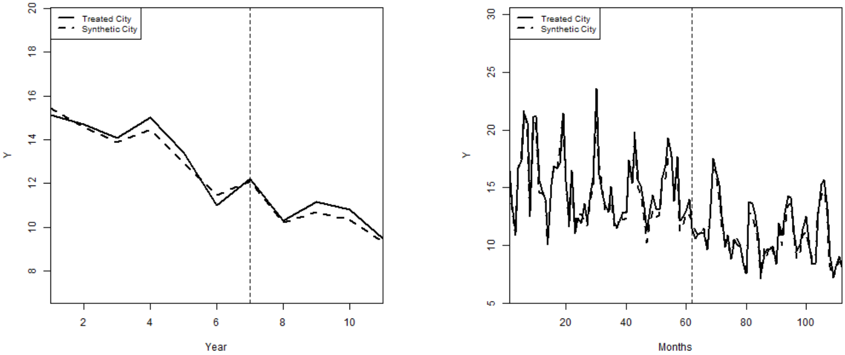
Dependent Variable:	pm25
Model:	(1)
Variables	
operating × treatcity × dowFriday	-0.48 (0.27)
operating × treatcity × dowMonday	-0.57 (0.33)
operating × treatcity × dowSaturday	-0.53 (0.35)
operating × treatcity × dowSunday	-0.50 (0.31)
operating × treatcity × dowThursday	-0.78** (0.25)
operating × treatcity × dowTuesday	-0.56* (0.25)
operating × treatcity × dowWednesday	-0.61** (0.25)
Fixed-effects	
dow_my	Yes
Address	Yes
Fit statistics	
Observations	29,936
Adjusted R^2	0.43

Clustered (Address) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Synthetic Control Methodology

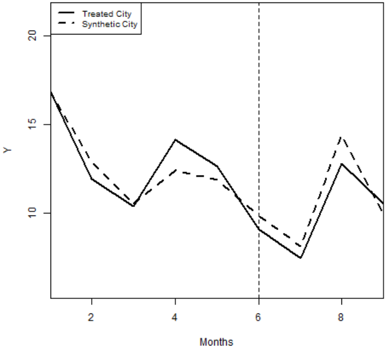
- We use the synthetic control method described in Abadie et al. (2008)
- To construct a synthetic city for each treated city, we minimize the gap in PM2.5 trends before construction time.
- We also include 47 meteorology variables, CO_2, NO_2, and SO_2 emissions from power plants in the same county, and number of public bus and car trips.

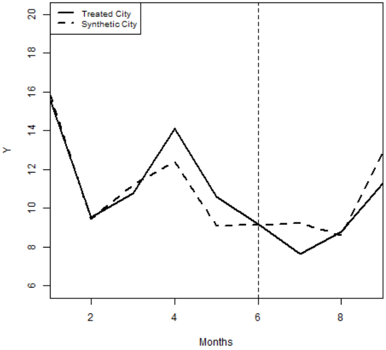
SYC Results for Charlotte, NC



SYC Results for Charlotte, NC

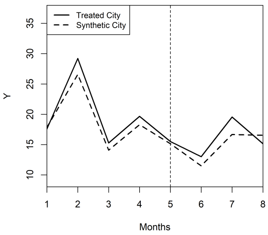
January and February averages of PM2.5 on Thursdays





SYC Results for Charlotte, NC

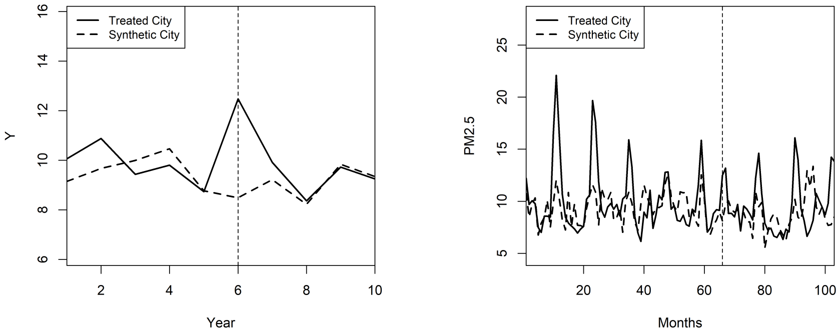
July averages of PM2.5 on Thursdays



weights	unit names
0.418	Fayetteville, NC
0.582	Winston-Salem, NC

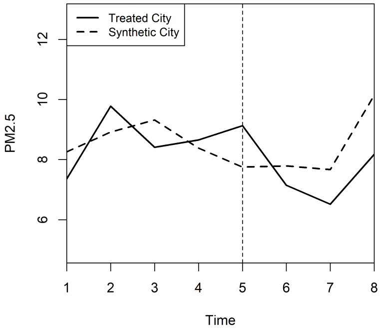
SYC Results for Phoenix-Mesa, AZ

Annual and monthly averages



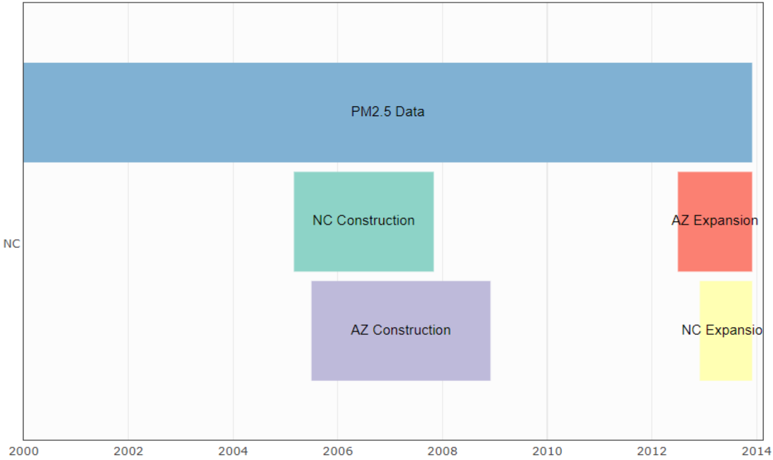
SYC Results for Phoenix-Mesa, AZ

June averages



weights	unit names
0.353	El Pason, TX-NM
0.63	Flagstaff, AZ
0.006	Las Cruces, NM
0.11	Tucson, AZ

SYC with Two Treatment Cities?



SYC with Two Treatment Cities

Generalized Synthetic Control Method: Causal Inference with Interactive Fixed Effects Models (Xu, 2017)