

# 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.**

## Data: PM2.5 and Meteorology

- ▶ PM2.5 data comes from Di et al. (2019), which provides daily PM2.5 concentrations in grid cells at a resolution of 1 km for the years 2000 to 2016.
- ▶ To consider meteorological conditions, we include 48 land surface meteorological variables provided by NASA Global Land Data Assimilation System Version 2. The data set provides rasters with a raster of 0.25 x 0.25 degree daily.
- ▶ For each treated city, we identified which highway light rails could potentially serve as a substitute, and we extracted daily levels of PM2.5 and our meteorological variables from areas within 1 km of those highways.

# 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.

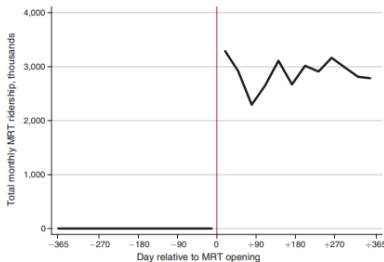
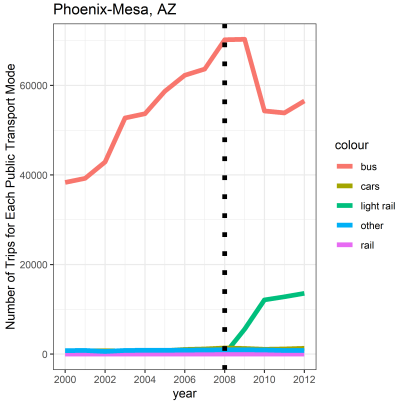
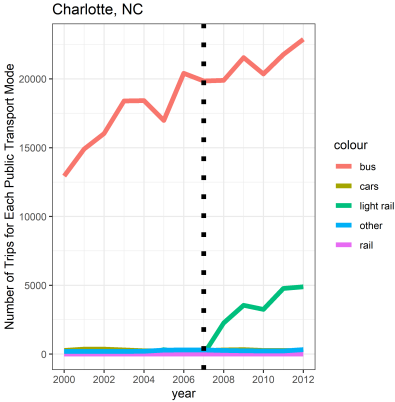


FIGURE 1. RIDERSHIP ON THE TAIPEI METRO

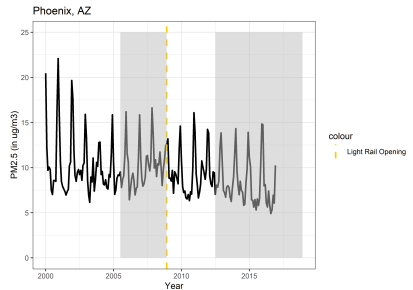
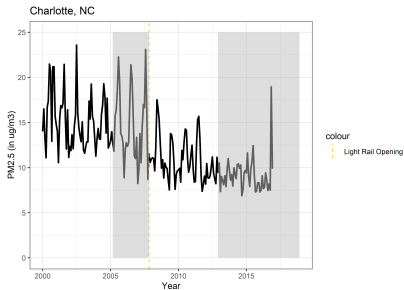
Figure 1: Ridership Data from Chen and Whalley (2012)

# Literature Review

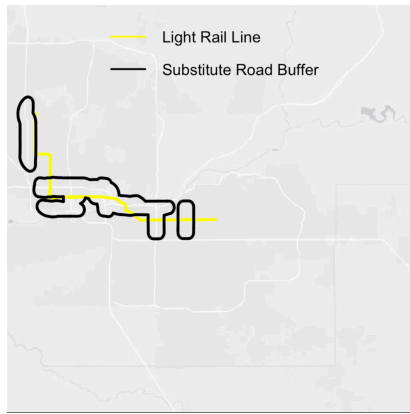
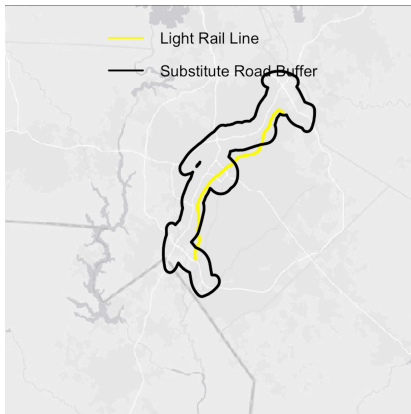


# Literature Review

- ▶ *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.
- ▶ Their study used annual PM2.5 data, going back only up to 3 years before opening, which can confound with construction time.



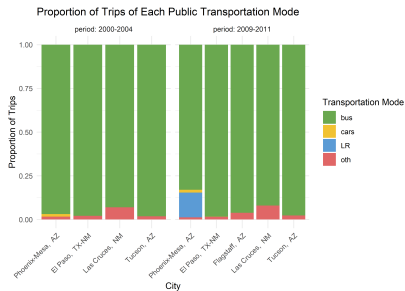
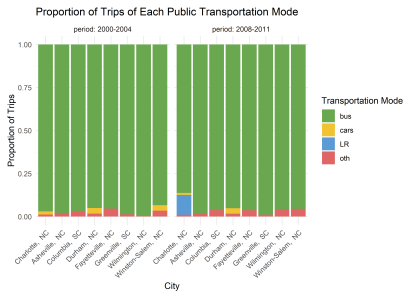
# Treated Area





# Untreated Area

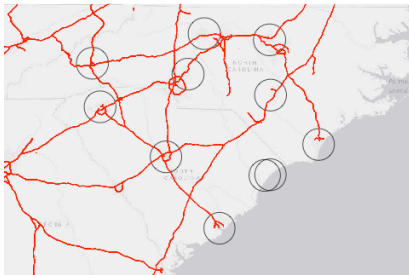
For each control city, we find cities with no light rails, no subways, and similar public transportation profiles.



## 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 PM<sub>2.5</sub> 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.

$\mu_{it}$  are city-day of week-month-year fixed effects.

# DiD Results

Table 1: DiD Results for Charlotte, NC

Dependent Variable: Model:	(1)	(2)	pm25 (3)	(4)
<i>Variables</i>				
operating $\times$ treatcity	-0.51 (0.32)	-0.54 (0.31)	-0.52 (0.28)	-0.57* (0.28)
Wind_f_tavg	-2.1*** (0.54)	-2.0*** (0.52)	-3.4*** (0.53)	-2.4*** (0.54)
Wind_f_tavg_sq			0.42*** (0.11)	0.28** (0.12)
Wind_f_tavg_cu			-0.03** (0.009)	-0.02 (0.010)
<i>Fixed-effects</i>				
dow_m	Yes		Yes	
Address	Yes	Yes	Yes	Yes
dow_my		Yes		Yes
<i>Fit statistics</i>				
Observations	29,936	29,936	29,936	29,936
Adjusted R <sup>2</sup>	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: Model:	pm25 (1)
<i>Variables</i>	
operating $\times$ treatcity $\times$ dowFriday	-0.48 (0.27)
operating $\times$ treatcity $\times$ dowMonday	-0.57 (0.33)
operating $\times$ treatcity $\times$ dowSaturday	-0.53 (0.35)
operating $\times$ treatcity $\times$ dowSunday	-0.50 (0.31)
operating $\times$ treatcity $\times$ dowThursday	-0.78** (0.25)
operating $\times$ treatcity $\times$ dowTuesday	-0.56* (0.25)
operating $\times$ treatcity $\times$ dowWednesday	-0.61** (0.25)
<i>Fixed-effects</i>	
dow_my	Yes
Address	Yes
<i>Fit statistics</i>	
Observations	29,936
Adjusted R <sup>2</sup>	0.43

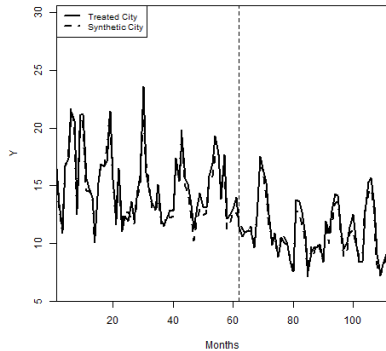
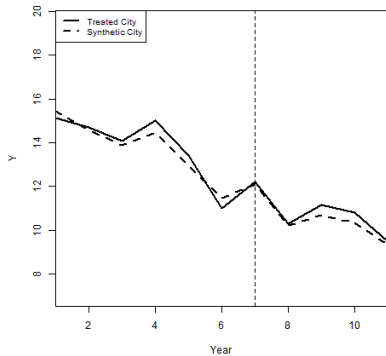
*Clustered (Address) standard-errors in parentheses*

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# Synthetic Control Methodology

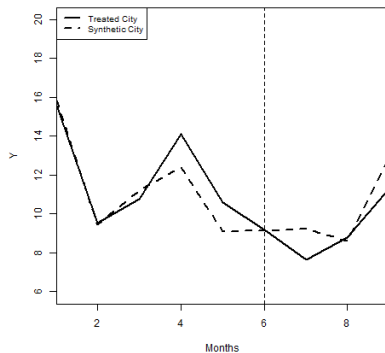
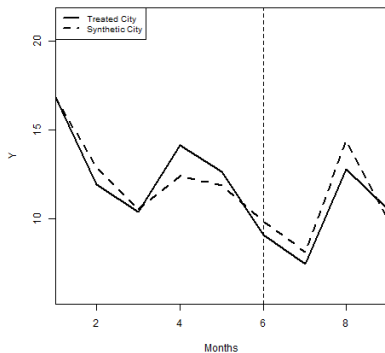
- ▶ We use the synthetic control method described in Abadie et al. (2008)
- ▶ To construct a synthetic city for each treated city, we minimize the gap in PM2.5 trends before construction time.
- ▶ We also include 47 meteorology variables, CO2, NO2, and SO2 emissions from power plants in the same county, and number of public bus and car trips.

# SYC Results for Charlotte, NC



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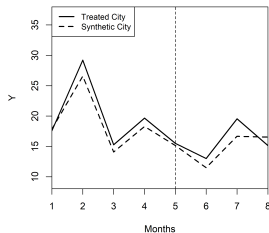
January and February averages of PM2.5 on Thursdays





# SYC Results for Charlotte, NC

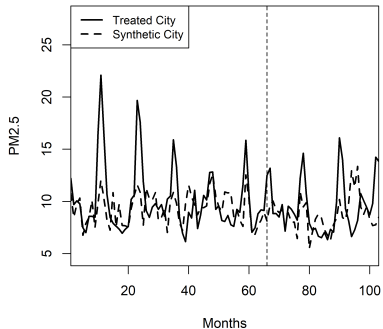
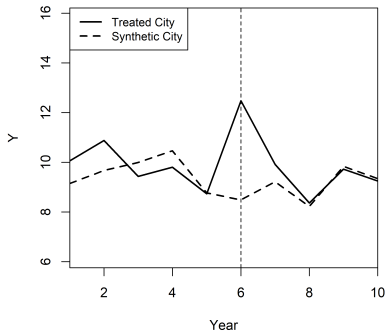
July averages of PM2.5 on Thursdays



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

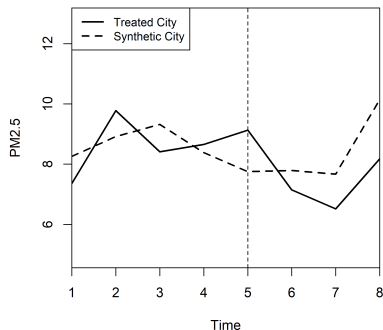
# SYC Results for Phoenix-Mesa, AZ

## Annual and monthly averages



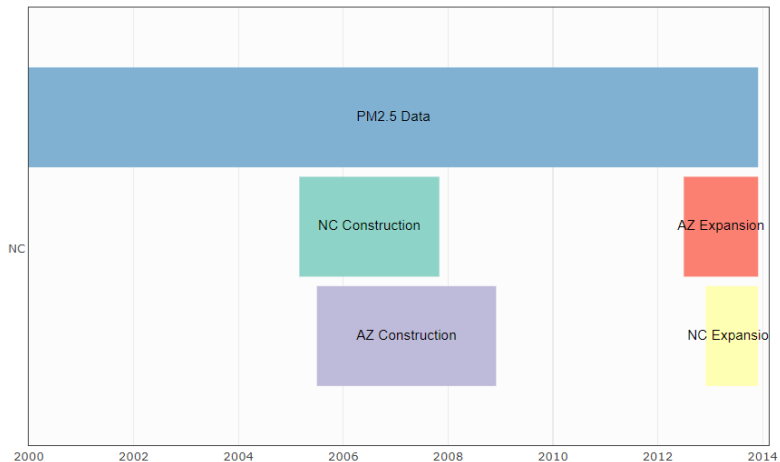
# SYC Results for Phoenix-Mesa, AZ

June averages



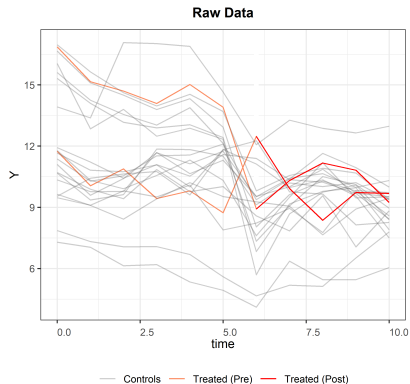
weights	unit names
0.353	El Pason, TX-NM
0.63	Flagstaff, AZ
0.006	Las Cruces, NM
0.11	Tucson, AZ

# SYC with Two Treatment Cities?



# SYC with Two Treatment Cities

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



**Treated and Counterfactual Average:**

