Estimation of 1990 PM2.5 and Pollution Reductions in Mexico City

Summary

We would like to calculate PM2.5 concentrations in Mexico City in 1990 and the life expectancy gains from subsequent air quality improvements. Since the earliest year covered by the AQLI's satellite-derived PM2.5 data is 1998, we use Mexico City's monitor data dating back to 1990. At that time, most monitors only measured total suspended particulates (TSP) or PM10.

For the five monitoring stations for which we are able, we impute 1900 PM2.5 values by assuming constant PM2.5/PM10/TSP ratios over time at each monitor location. Then, since monitor- and satellite-based pollution measurements for a given location may be systematically different, for each monitor location, we scale the imputed 1990 PM2.5 values by the average ratio of satellite and monitor measurements post-1998 to be consistent with the AQLI's satellite data.

Finally, we combine the 1990 PM2.5 estimates with the AQLI's PM2.5 data for more recent years to calculate changes in PM2.5 concentrations and life expectancy gained due to the pollution reductions. We take a simple average across the monitor locations to get results pertaining to Mexico City as a whole.

Data Sources

red_manual_particulas_susp.csv: From the Mexico City Ministry of the Environment, daily readings for PM2.5, PM10, and TSP for each monitoring station, from 1989 to present, were downloaded from http://www.aire.cdmx.gob.mx/opendata/red_manual/red_manual_particulas_susp.csv.

satellitePM25_CDMX_edomex.dta: Station locations were determined from http://www.aire.cdmx.gob.mx/default.php?opc=%27ZaBhnmI=&dc=%27ZA==. For those municipalities, we merge in the AQLI's own municipality-level data for Mexico City and the State of Mexico for 1998 to the latest available year.

Assumptions

1. PM2.5 particulates are a sub-group of PM10 particulates, which in turn are a subgroup of TSP. We assume that at each location, the ratios PM2.5/PM10, PM10/TSP, and PM2.5/TSP are constant over time, and are equal to the average of observed annual ratios.

Procedure

Impute monitor-based 1990 PM2.5

For each monitor location,

1. Aggregate the daily level data to monthly, then annual. Aggregating to the monthly level first ensures that the annual average will represent the whole year in a balanced way.
2. Use all years when multiple PM types are measured to calculate location-specific average ratios $\frac{\text{PM2.5}}{\text{PM10}}$, $\frac{\text{PM2.5}}{\text{TSP}}$, $\frac{\text{PM10}}{\text{TSP}}$. Make the simplifying assumption that in all years, these ratios hold.

3. Since only PM2.5 was not monitored in 1990, it needs to be imputed. If PM10 was monitored in 1990, then we calculate

$$\text{PM2.5}_{1990}^{\text{mon}} = \text{PM10}_{1990} \cdot \frac{\text{PM2.5}}{\text{PM10}}. \tag{1}$$

If PM10 was not monitored in 1990 but TSP was, then we calculate

$$\text{PM2.5}_{1990}^{\text{mon}} = \text{TSP}_{1990} \cdot \frac{\text{PM2.5}}{\text{TSP}} \tag{2}$$

if there were later years for which both PM2.5 and TSP were monitored and the $\frac{\text{PM2.5}}{\text{TSP}}$ ratio is available. If the $\frac{\text{PM2.5}}{\text{TSP}}$ ratio is not available but $\frac{\text{PM2.5}}{\text{PM10}}$ and $\frac{\text{PM10}}{\text{TSP}}$ are, then we calculate

$$\text{PM2.5}_{1990}^{\text{mon}} = \text{TSP}_{1990} \cdot \frac{\text{PM10}}{\text{TSP}} \cdot \frac{\text{PM2.5}}{\text{PM10}}. \tag{3}$$

We use imputation 1 where possible, imputation 2 where imputation 1 is not possible, and imputation 3 where neither imputations 1 nor 2 is possible. In all, we are able to impute 1990 PM2.5 for five monitor locations.

Scaling monitor-based imputed PM2.5 to satellite data

The AQLI's satellite-derived PM2.5 data generally differs somewhat from what monitors record, e.g. because monitors record the pollution at specific point locations while satellite data records the average pollution across space. In order to make an apples-to-apples comparison between the latest year's satellite-derived PM2.5 data and the 1990 estimates, we need to scale the 1990 estimates to be consistent with the satellite data.

For each location and each year starting in 1998 when PM2.5 was monitored, we take the ratio of AQLI's PM2.5 and the monitor's PM2.5. We then average the ratios across years.

In other words, let $\{Y\}$ be the set of years within 1998-2018 in which PM2.5 was monitored at a given location. For each of those years Y, let $\text{PM2.5}_Y^{\text{AQLI}}$ be the PM2.5 in that county-year according to the AQLI's satellite data, and let $\text{PM2.5}_Y^{\text{mon}}$ be the PM2.5 in that location-year as measured by the monitor. The average ratio we want is

$$R = \frac{1}{|\{Y\}|} \sum_{\{Y\}} \frac{\text{PM2.5}_Y^{\text{AQLI}}}{\text{PM2.5}_Y^{\text{mon}}} \tag{4}$$

For our 5 monitor locations, R ranges from 0.94 to 1.26, with mean 1.12.

Now, the satellite-adjusted imputed 1990 PM2.5 is $\text{PM2.5}_{1990}^{\text{mon}}$ from imputations (1) and (2) scaled by (i.e. multiplied by) R from (3):

$$\text{PM2.5}_{1990}^{\text{AQLI}} = R \cdot \text{PM2.5}_{1990}^{\text{mon}}$$

Life expectancy

Per Ebenstein et al. (2017), gain in life expectancy from 1990 to 2018 due to PM reduction is:

$$(\text{PM2.5}_{1990}^{\text{AQLI}} - \text{PM2.5}_{2018}^{\text{AQLI}}) * 0.098 \text{ years}/(\mu g/m^2).$$