City Population and CO2 Footprint

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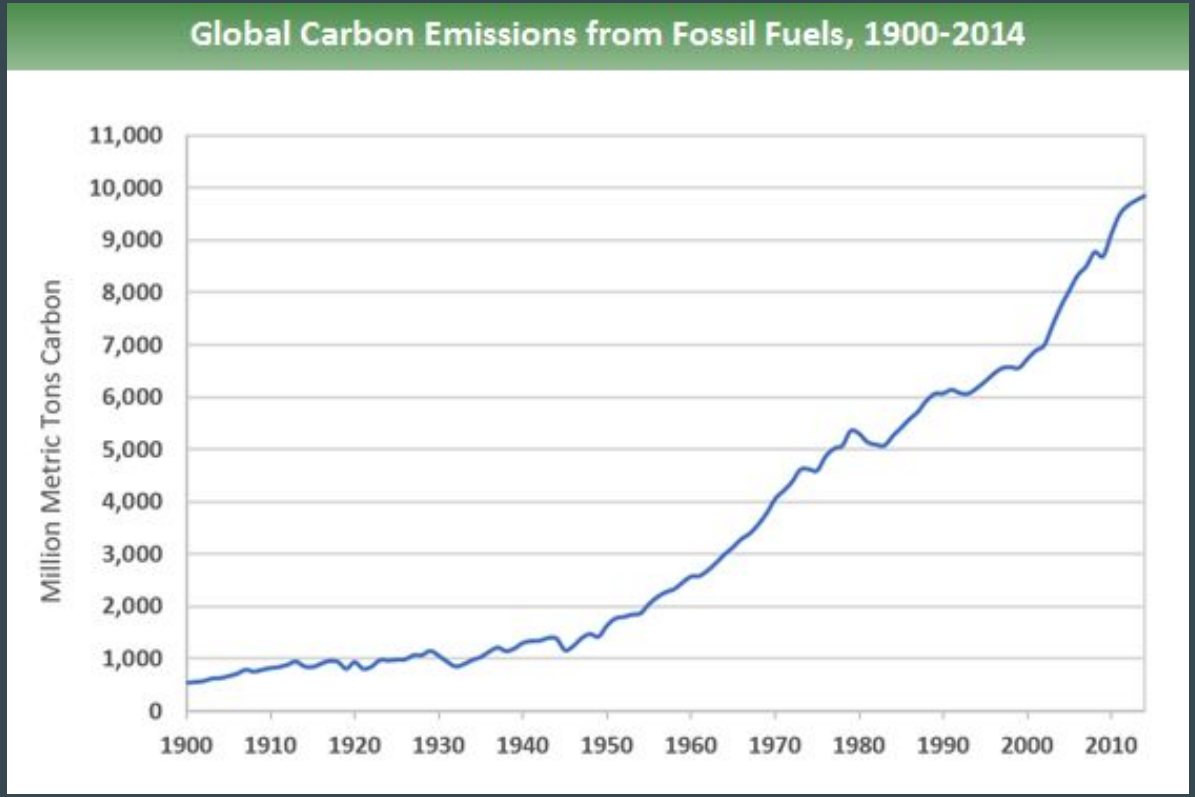
Introduction

- CO2 (the most dangerous and prevalent greenhouse gas) is at the highest levels ever recorded
- Fossil fuel use is the primary source of CO2
  - Also from direct human-induced impacts
- Detrimental environmental and health effects
- Trump withdrawing the US from the Paris Climate Agreement



Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2017.

Description of Project

- Is there a correlation between population (city) size and carbon footprint (Mt CO2)?
  - Confirm dramatic relationship between these variables
- Curve fitting model of CO2 emission data by city
  - Global and per continent analysis
- Taking note of outlier data points (cities) can serve as examples of which environmental policies to follow or avoid
- Observe which continents produce the highest amounts of CO2 emissions

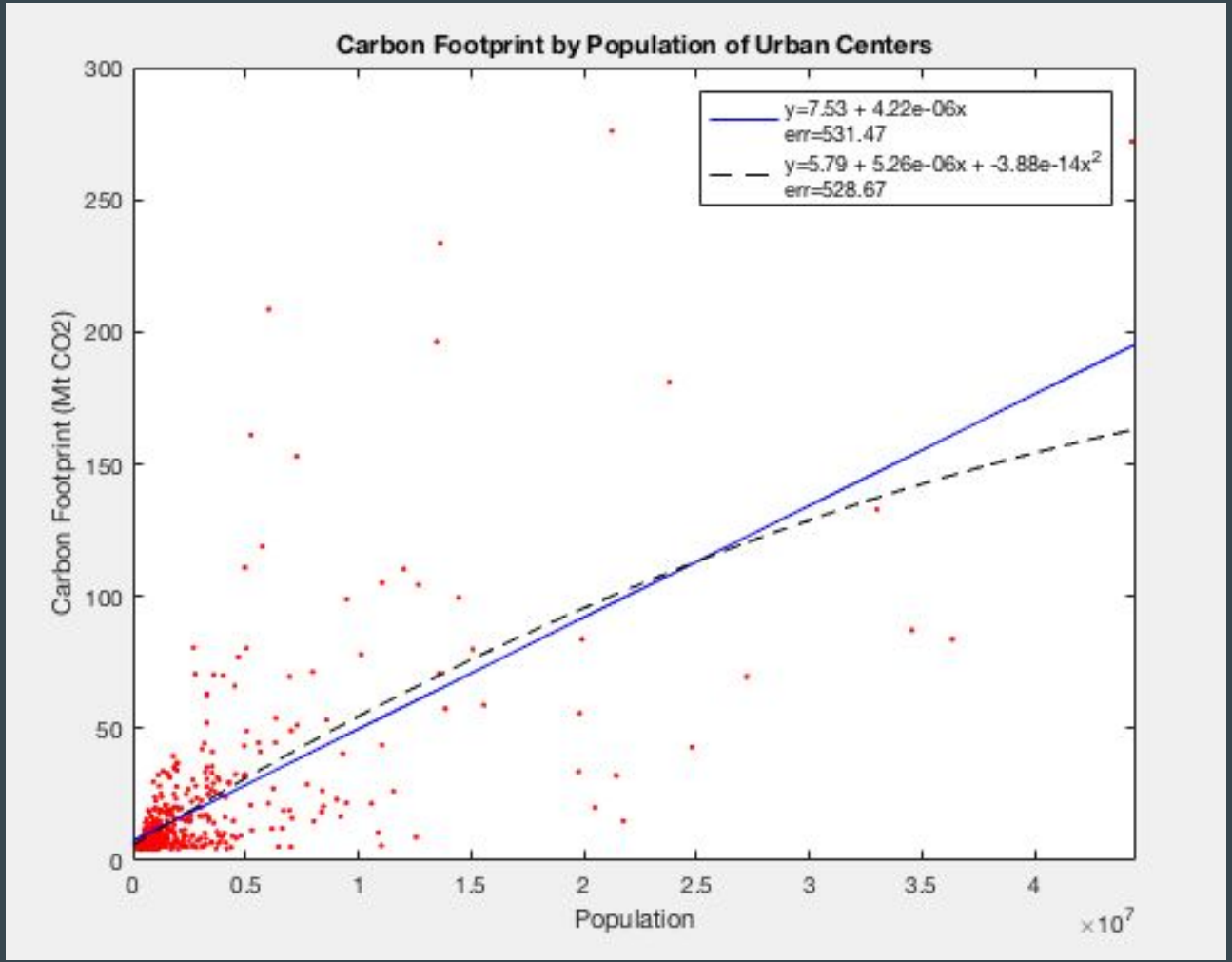
Methods

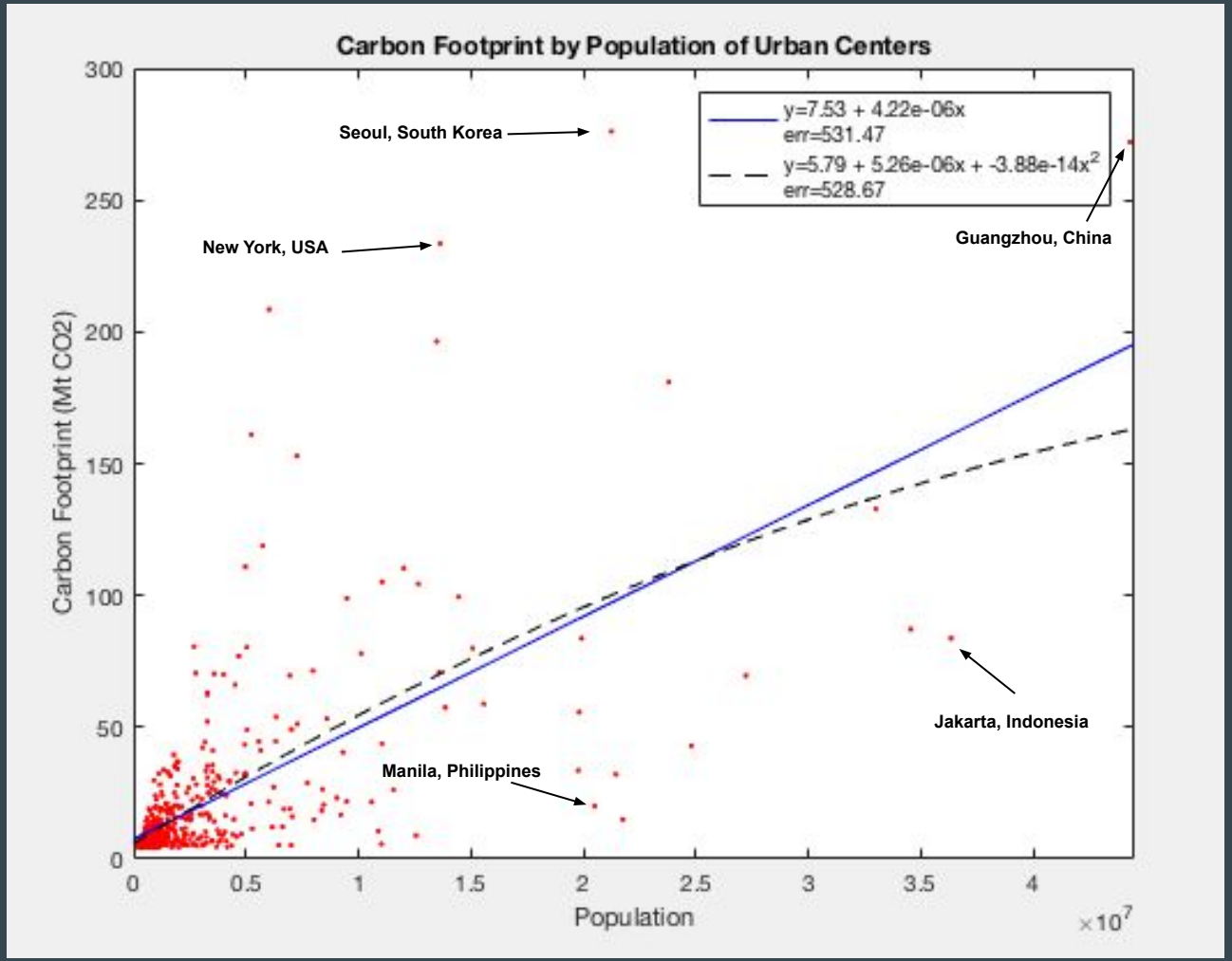
- Identify a CO2 footprint dataset with the desired information and of reasonable size, ideally with population size
  - We hypothesize there's some relationship between the population size of city and its CO2 emission because humans emit CO2 in their daily activities
- Write curve fitting code in MatLab based on the matrix approach to the least-squares problem
- Curve fit a linear and quadratic model for global data and data for each continent

Curve Fitting

$$X = \begin{bmatrix} 1 & x_1 \\ 1 & x_2 \\ & \dots \\ 1 & x_n \end{bmatrix} \qquad \beta = \begin{bmatrix} \beta_0 \\ \beta_1 \end{bmatrix} \qquad y = \begin{bmatrix} y_1 \\ y_2 \\ \dots \\ y_n \end{bmatrix}$$

$$X\beta = y \rightarrow X^T X\beta = X^T y$$


Carbon Footprint by Population of Urban Centers
y=7.53 + 4.22e-06x
err=531.47
y=5.79 + 5.26e-06x + -3.88e-14x^2
err=528.67
Carbon Footprint (Mt CO2)
Population
×10^7
0
50
100
150
200
250
300
0
0.5
1
1.5
2
2.5
3
3.5
4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Seoul, South Korea
New York, USA
Guangzhou, China
Jakarta, Indonesia
Manila, Philippines
Carbon Footprint (Mt CO2)
Population
×10^7
0
50
100
150
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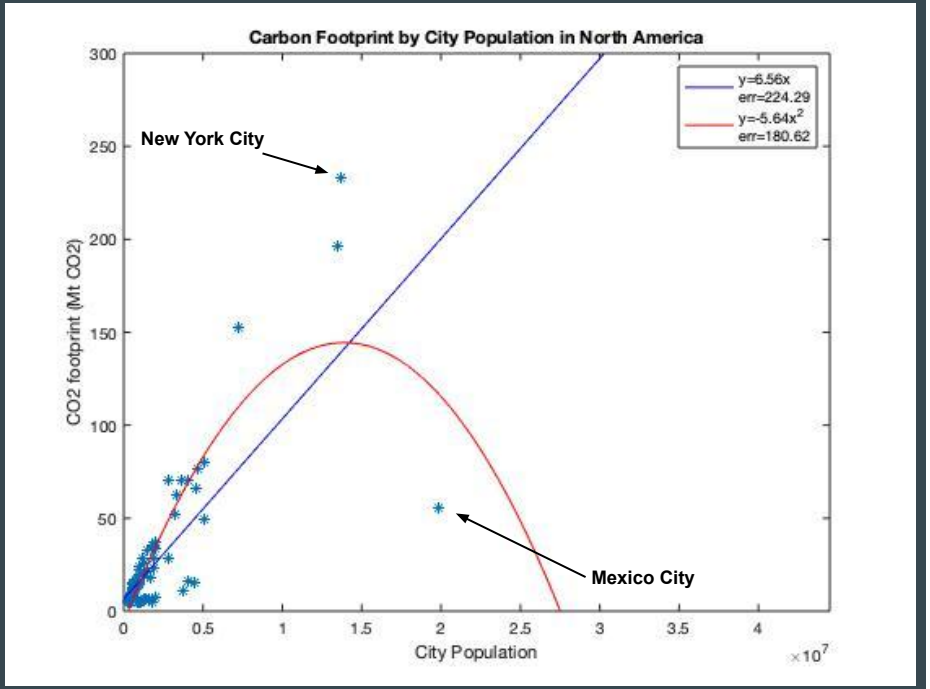
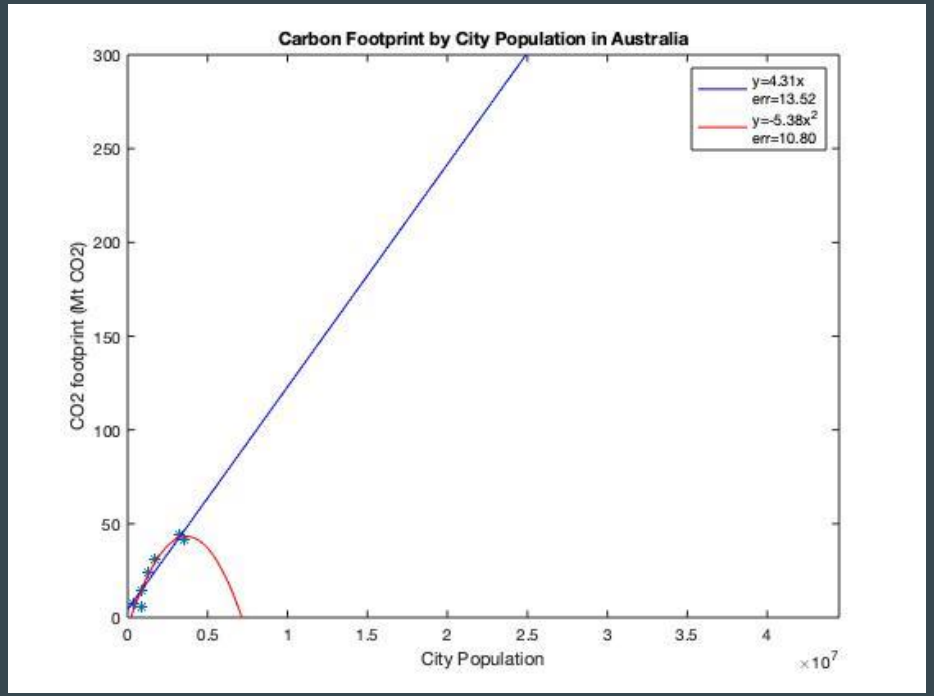
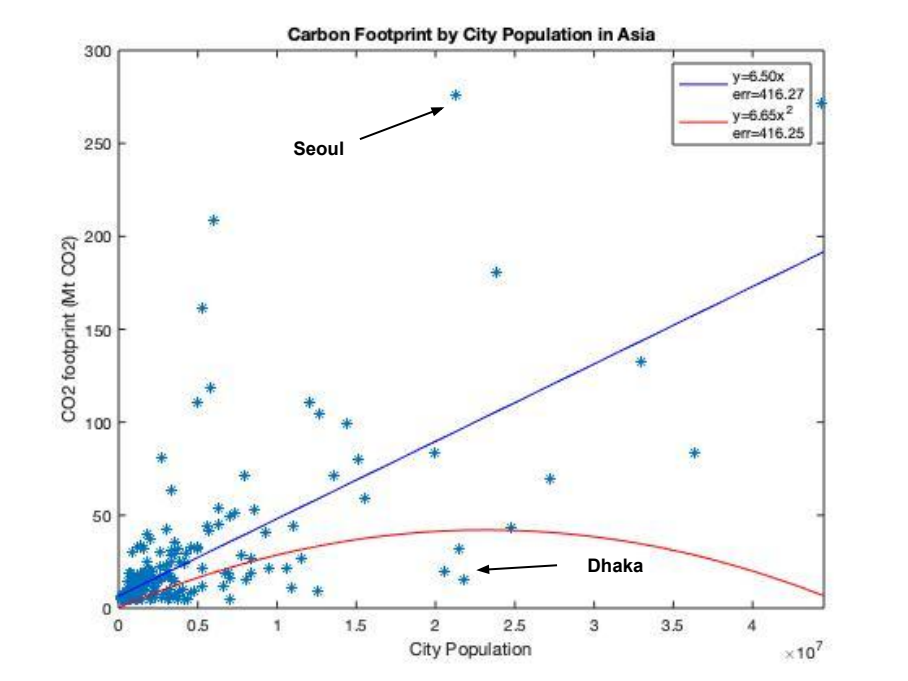
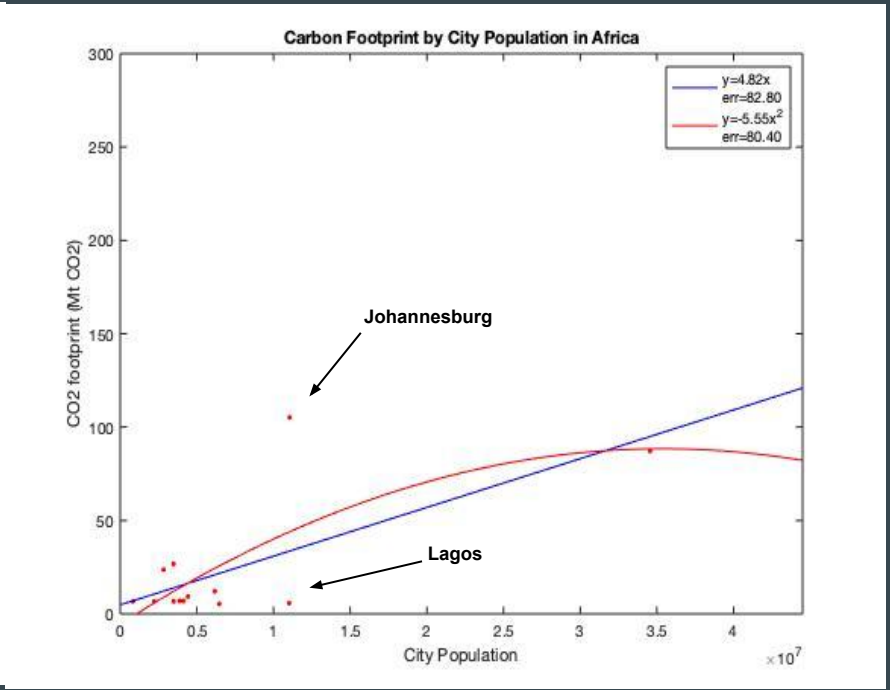
Results: by Continent



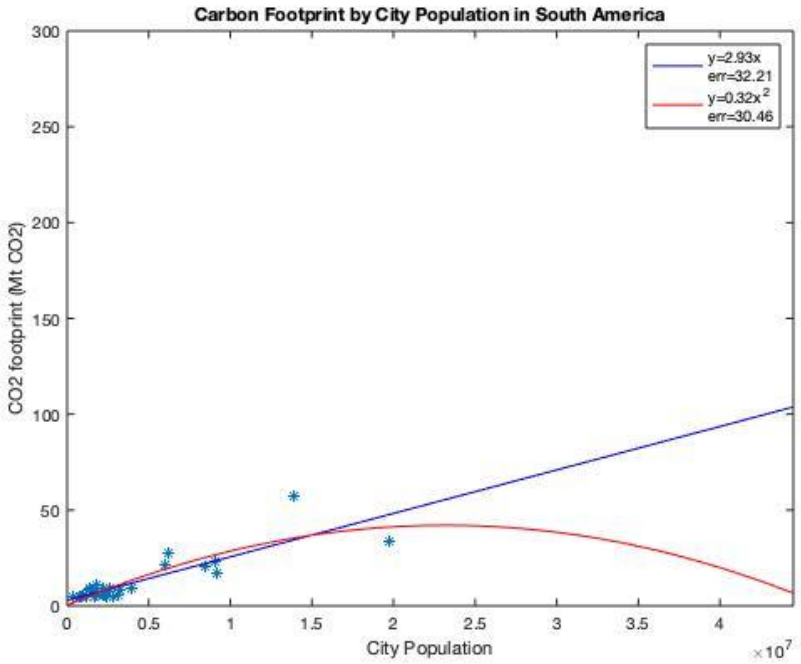


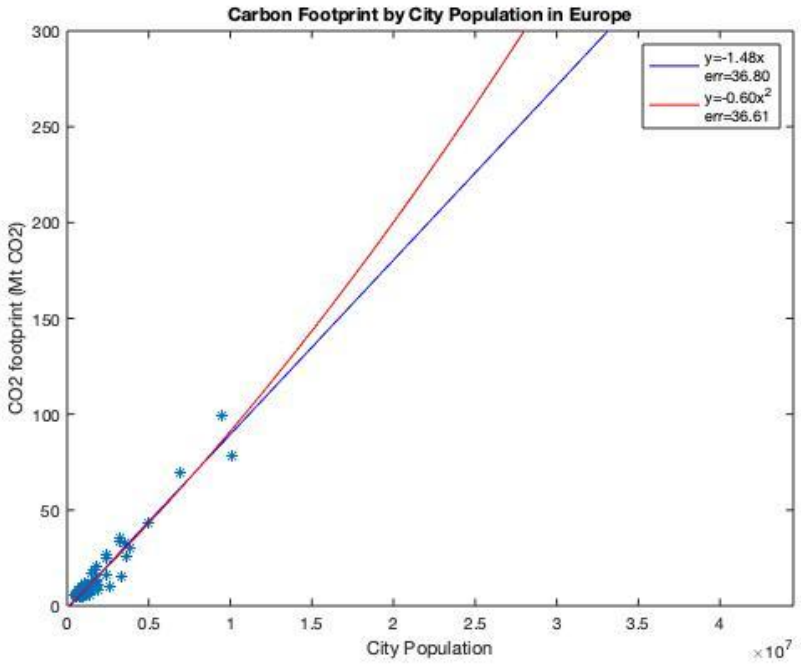
Results: by Continent





Results: by Continent





Discussion and Observations

- Regional fits tend to stronger than global fits, with weaker fit appearing on continents that are more economically heterogeneous
  - Linear fits for South America, Europe, North America, Australia are stronger
  - Linear fits for Asia and Africa are weaker
- Linear fits get steeper for more wealthy (on average) continents indicating more CO_2 emission per capita
  - Different levels of economic development have different per capita carbon emission tendencies?
    - E.g. poorer countries tend to rely on coal and wood fuel but don't drive as much, richer countries have renewable energy but use more electricity
- Suggests where the most impactful policy changes can be made on climate change
  - Curve-fitting identifies which cities have high per-capita emissions even relative to peers
  - Investigate why these cities have higher carbon emissions than expected
  - Major cities as outliers: what is role of urban policy is limiting emissions?

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