Modeling City Scaling Relations in France

By Lorenz Menendez

Introduction

My project sought to verify that the city scaling relations in the United States, Germany and China (Bettencourt, et al.) still apply to cities in France. I chose to model French cities because it's not immediately obvious that French cities would follow the same scaling relations as in other countries. They have a unique economic, political and cultural history (Cattan, et al. & Cusin).

The model used publicly available data to represent the relationship between population and various urban indicators in French cities. The ultimate goal was to compare my results with Bettencourt's analysis, and discuss the similarities and differences.

Background

The core of this project involved calculating scaling exponents (β) to the power law to interpret the significance of urban indicators with regards to their underlying urban dynamics. The power law is often used in biology "for revealing underlying dynamics and structure" (Bettencourt, et al). The analysis of organisms' biological indicators has a "clear counterpart" in social systems (Macionis, et al. & Levine). Therefore, it would be appropriate to use it in the context of urban indicators.

The following urban indicators were studied in my project. The specific indicators I chose are each proxying an urban construct identified by Bettencourt. The constructs are then related to one of two underlying urban dynamics based on their anticipated scaling exponent, β. The two underlying dynamics describe the benefits of cities at a basic level (Kates, et al).

Construct (Bettencourt)	*Economies of Scale in Infrastructure*	*Fulfillment of Human Needs*	*Rate of Innovation*	*Skilled and Educated Workforce*
Urban Indicator Proxy	Number of Gas Stations	Total Employment Total Number of Businesses	New Businesses	Number of Artisans, Managers and CEOs Number of Academics
Anticipated β range	$\beta < 1$	$\beta = 1$	$\beta > 1$	
Underlying Urban Dynamic (Kates, et al.)	*Material Economies of Scale*	—	*Innovation and Wealth Creation from social interactions*	

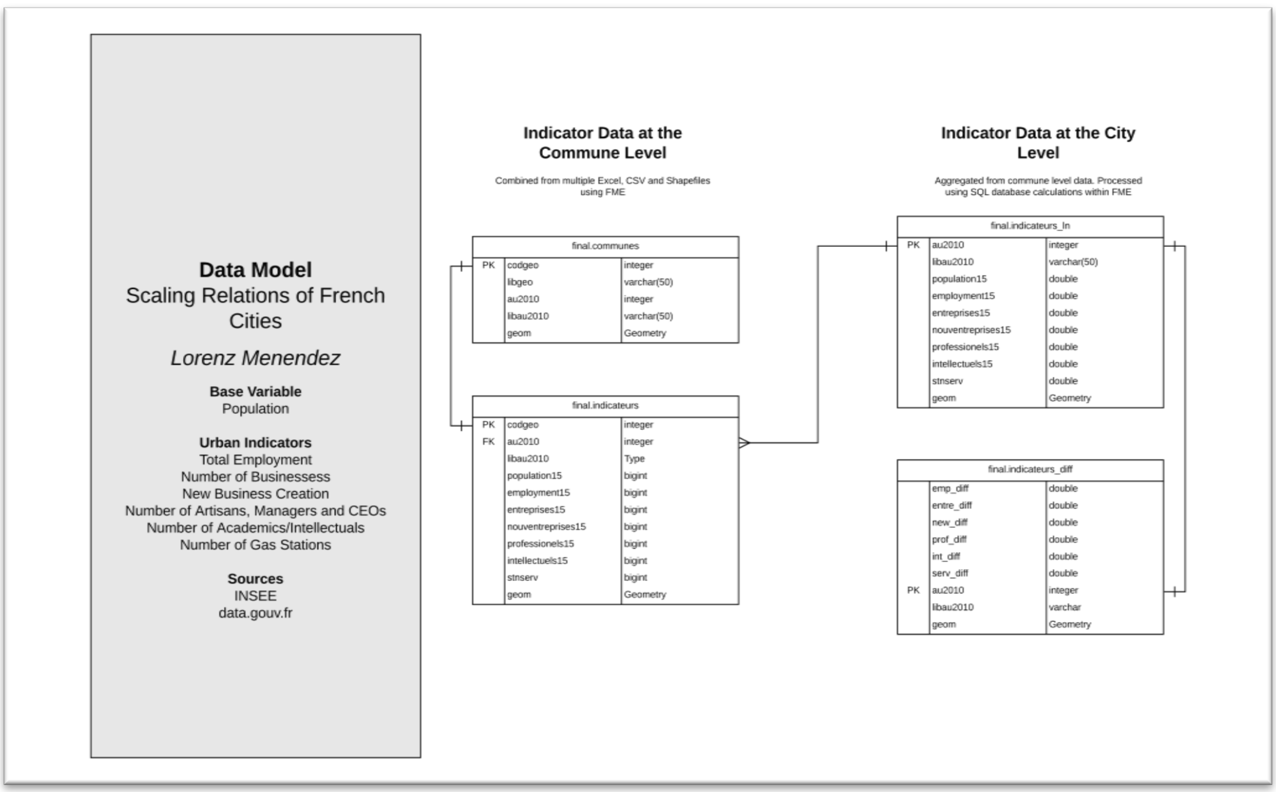
Goals and Objectives

The objective was to use a PostGIS database to calculate and store data related to the seven urban indicators studied for each city. Then, this project modeled scaling relations by calculating a β value for each urban indicator stored in the database using a SQL query. β could then interpreted using Bettencourt's framework, as described in the following section and visualized using a graph in GeoDa.

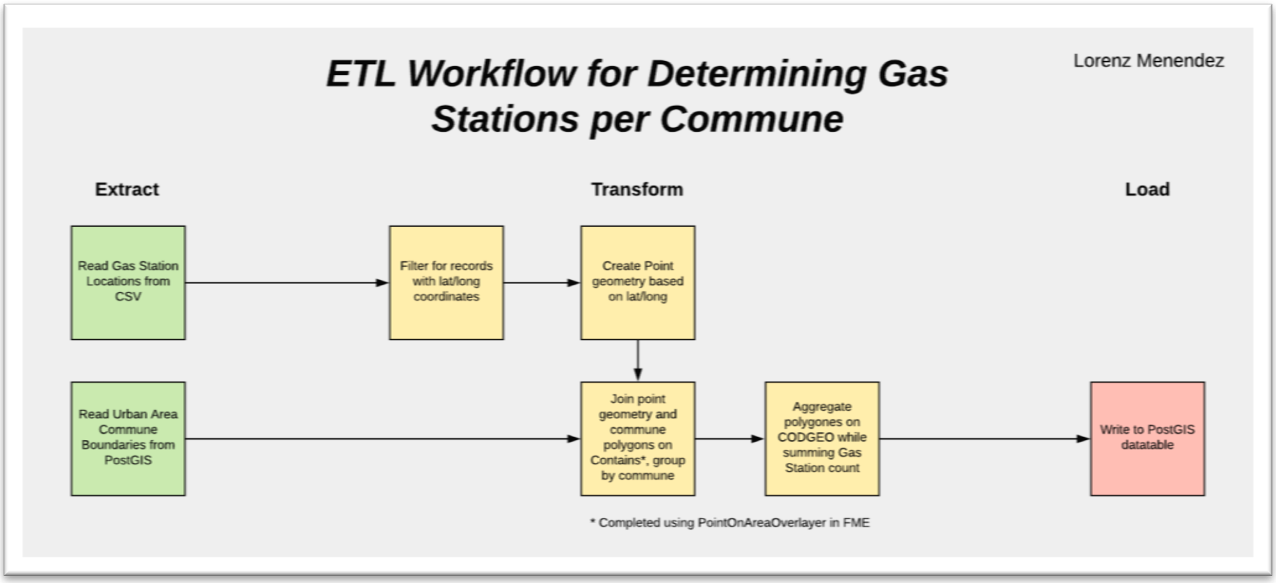
Additionally, this project visualized outlier urban areas, meaning urban areas with an urban indicator value that differs from our model's expected value. For example, visualizing cities that have many more businesses for their given size than expected.

Solution Framework

This project relied heavily on the integration of spatial and non-spatial data from multiple Excel, CSV, and Shapefiles in FME to generate indicator data at the commune level. I created an ETL workflow that performed spatial/non-spatial joins and quality assurance test across multiple data streams. The streams were compiled for writing to *final.communes* in PostGIS.



One of my spatial urban indicators required taking a CSV of point-data, representing the location of gas stations in France to determine the count of gas stations per commune. My ETL workflow was as follows.



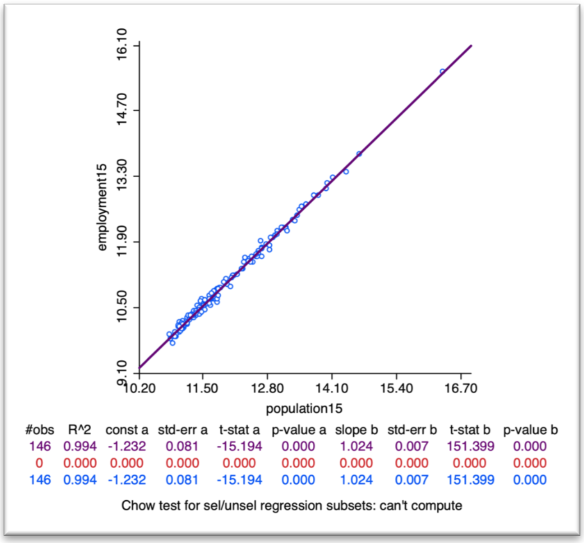
I first had FME translate the non-spatial lat/long columns into points while filtering for gas stations without lat/long data. Then, FME performed a "contains" spatial join of the points on the commune polygons, grouped by commune. Since some of the communes are discontinuous, I then had to aggregate by the polygon's geocode (PK) while summing the count of gas stations. Finally, I wrote to *final.communes*.

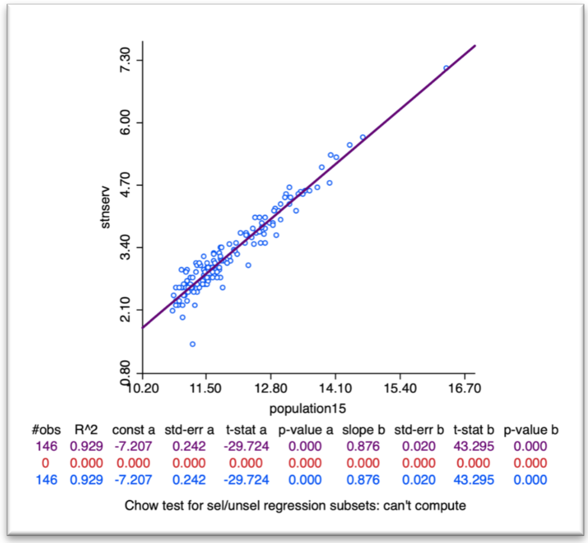
I used FME in conjunction to PostGIS to make data wrangling clearer and more thorough. With FME, I could see data flow through the ETL process in real-time and troubleshoot as I went along. I could also see where data loss occurred and at what magnitude.

Results & Discussion

Linear Regression Analysis

The following are the graphical results from GeoDa's linear regression analysis for Employment (left) and Number of Gas Stations (right) as a function of population. urban indicator across all French cities. You can see the slope "b" (β), as well as the fit "R^2", and constant "a" (Y_0) in the table at the bottom.



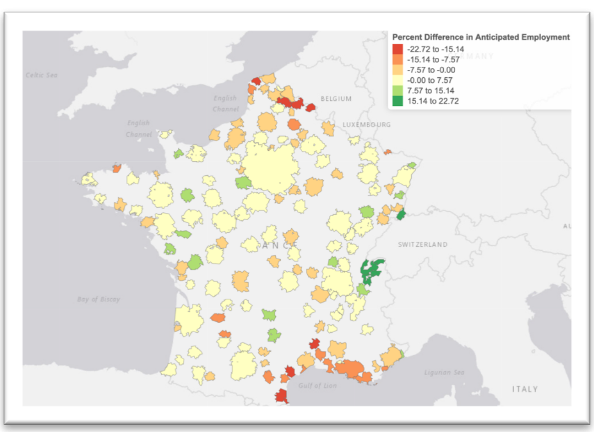


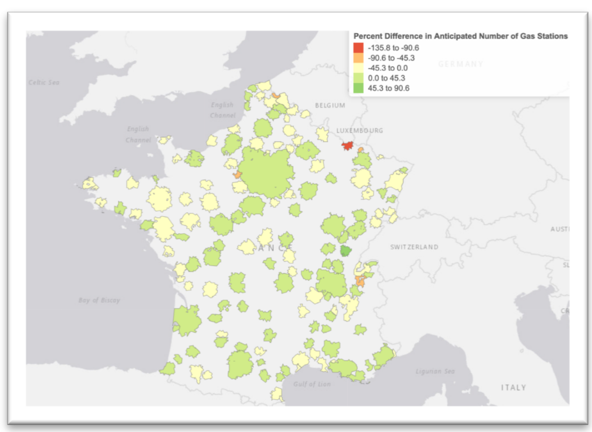
We see that the trends for French urban indicators are roughly the same as the American, German and Chinese cities from Bettencourt's paper. A slope of $\beta \approx 1$ suggests that having a job an individual need, meaning that there is a 1:1 matching of jobs to residents of a city, regardless of city size. A slope of $\beta < 1$ in the gas station indicator suggests that cities benefit from a more efficient use of gas stations as population increases.

Visualization of Outliers

The following choropleth map visualize the locations of statistically outlying cities with regards to Employment and Number of Gas Stations. Cities with more intense green or red shading are farther above or below the scaling line, meaning that they are outliers. These maps help better understand the data, even though the spatial aspect is tangential to the project's non-spatial data analysis.

More graphs and interactive visualizations for all six key variables I studied can be found [here]().





In the Employment map, we notice that there seem to be clusters of “underemployment” in cities in Northern France and along the French Riviera.

The northern cluster might be explained by the fact that the Lille region is an industrial area in decline. As for the southern cluster, I speculate that they are outliers since these cities are known to house many pensioners who move from other cities to enjoy the warm weather and a cheaper cost of living. But, a more formal analysis is required to confirm my hypotheses.

The Gas Station outlier map does not seem to show any specific clustering action.

Further Work

In the future, I would like to iterate on this project by a web page where you can toggle between all of the visualization products I’ve created. This will make my results more accessible and user friendly to a broader audience.

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