Urban Sprawl and Emissions on the Urban Environment

Brett Jones

The University of Akron

Department of Economics

Spring 2021

Table of Contents

Abstract

Urban Sprawl is an occurrence that happens when workers leave the cities in favor of greater space due to additional income, the want for private land ownership or simply increased space. This is more preferred now more than ever with the COVID-19 outbreak disabling urban Central Business Districts (CBD's). With a clear negative externality to individuals living in high density city areas, what are the environmental repercussions of individuals whose preferences have shifted to living in the suburbs?

Examining AQI data, labor statistics data and census data from 30 of the largest cities in the U.S. and examining them over the past 20 years, results indicate that a cities density and population play almost no effect on a cities air quality while air quality itself has been increasing gradually (for most cities) over the past 20 years. Urban Growth Boundaries (UGB) appear statistically to be effective in creating better air quality with cities that implement them.

In conclusion, because of micro economic data being scarce a time series analysis is limited. Literature suggests that a city's main culprit for emissions are from commuters, households and general energy usage. Recommendations are for U.S. Census to measure yearly commuter inflow and outflow data and EIA to showcase yearly city level energy consumptions or breakdowns.

1. **Introduction**

With the COVID-19 pandemic coming to a foreseeable close, urban living citizens all over the world will now have to decide whether to continue dense city living or suburban or rural living. While some citizens may continue to live in the city, there is much less risk to living in the suburban life. In the case of a potential exodus there will be negative externalities with these new living areas. Specifically, suburban environments outside the central business district, which are already high in emissions, will begin to see even higher emission outputs. This leads to the question: What are the environmental effects caused by urban sprawl? With this potential sudden increase in suburban living, what kind of effects are to be felt in this potential new living environment? What are the emissions that are involved with cities suffering from Urban Sprawl?

Why the emissions are larger in the surrounding area's than the city itself has multiple reasons. Transportation or vehicle emissions is a primary factor. The city of Atlanta, for example, has historically had an urban sprawl problem. In Bertaud and Richardson (2005) examination of Barcelona and Atlanta, the urban area of Atlanta (4,280km^2) is over 26 times larger than the city of Barcelona and yet is nearly it's equal in population of 2.5 million. In energy consumption per capita for private transportation, Atalanta eclipsed Barcelona by over 8 times, no doubt adding to the carbon foot print of Atlanta. Frumkin also adds, "The average person (in Atlanta) travels 34.1 miles in a car each day. More densely populated cities have far lower averages: 16.9 miles (Philadalphia), 19.9 (Chicago) and 21.2 (San Francisco)." (Fumkin, 2002. p. 2).

2. **Literature Review**

When understanding urban sprawl, the questions of what urban sprawl is and how is it measured is hazy. Urban sprawl is a modern multifaceted phenomenon occurring widespread within the past 100 years and it does not have a concise definition, which makes it difficult to form a basic model to measure it. Urban economists have proposed their own models with its study, but there isn't a universal model or formula that is agreed upon. Yasin, Yussof and Noor (2019) indicate at least five different theories in their article yet conclude that each has its strengths and weaknesses. That said, experts explain that urban sprawl can be broken down primarily into two sectors: public finance and urban economics.

The public finance relates to the Tiebout model. This is a model for community agglomeration that focuses on amenities pushing and pulling citizens to specific communities based on their public good preferences. "local public finance literature, on the other hand, emphasizes the desire of mobile households to segregate based on preferences for local taxes and amenities as well as the desire by such households to take advantage of peer externalities." (Nechyba/Walsh, 2004. p178.)

There are seven assumptions that establish this micro-local based model from the Musgrave-Samuelson's macro-federal model. The first is that all consumer-voters are fully mobile being able to choose where the voter wishes to live. Second, consumer-voters have complete information on differences between revenue and expenditure. Third, fourth and fifth respectively: There are large amounts of communities to select form, yet there are no employment restrictions among them which would impede choice and there are no positive or negative externalities affecting other communities through a communities publicly supplied goods. Finally, the sixth and seventh: Community with officials that track the demand of public goods have an optimal level (equilibrium) between population/public goods and communities will seek to attract consumer-voters if below their optimal population level to lower costs (taxes).

While the Tiebout model is divided to the public finance portion, there is an income effect which relates it to the side of economics. Assumptions six and seven influence urban sprawl as government officials at local communities, or cities, must be aware of their community's public goods demand or when confronted with overpopulation (inside their community) the results is an increase in public good prices (taxes). This leads to a decrease in disposable income which would be used for rent. Consumer-citizens then will have settle appropriately from the Central Business District (CBD) as rent and property values are higher the closer they are to the CBD. Families are also known to relocate to the suburbs to adjust to having to care for children as the suburb, while offering a lower rent, have the trade-off for better public goods. "Every resident who moves to the suburbs to find better schools, more parks, and so forth, is re-acting, in part, against the pattern the city has to offer." (Tiebout, 1954. p420.)

The urban economics portion on the other hand has to do with the transportation costs, zoning policy such as urban growth boundaries, rent ceilings and income effects. "In explaining this trend, the urban economics literature casts a primary focus on the role of declining transportation costs and rising incomes, with supporting forces emerging from various government tax, expenditure and zoning policies." (Nechyba/Walsh, 2004. p178.) Cities that have taken measures to restrict unchecked growth are known alternately as compact cities. Economically, these are cities who have higher densities which in turn minimize their transportation costs. These types of cities are uncommon in the United States with Portland, Oregon primarily being the best example. There is strong support of them in the United Kingdom and other parts of Western Europe. "In the UK this political support has been profound. It has resulted in guidance being issued to local planning authorities urging them to both adopt policies and make development control decisions which promote stronger urban containment" (Breheny, 1995, p. 86).

Not engaging in a more compact city style, or centralized city model, will in turn increase the transportation costs as living further from the CBD there is major negative externality of increased emissions. This is not only about commuters, but to the transportation sector that deliver goods as well. Simple goods need to be transported to create whichever complex good a business specializes in, then factor in the labor who is needed to go and extract those simple goods, and this leads to many moving pieces. The closer, or denser, all the pieces are to each other, the more environmentally efficient the supply chain. Wu's analysis on ***Urban Density and Carbon Emissions in China*** came to a similar conclusion "In other words, in terms of the transport sector, denser cities are more environmentally friendly than dispersed ones." (Wu, 2016. p492.)

There is enough data and literature to imply the correlation between urbanization and emissions. Both Sabayashi/Kaur and Martínez-Zarzoso/Maruotti draw conclusions of an inverted-U shaped relationship between urbanization and CO_2 emissions, much of this coming from transportation. Thus, decreasing transportation leads to decreases in emissions, leading to mass public transit being a great option to keep emissions low.

However, as a city continues to expand itself its own public transportation is underutilized for having to cover the extra ground, leading to citizens to depending on their own private transportation. Figure 1 provides a visual understanding while Bertaud/Franklin (2004) explains just how devastating sprawl can be to public transit. "The metro network in Barcelona is 99 kilometres long with 60 percent of the population living less than 600 meters from a metro station. Atlanta's metro network is 74 kilometres long (about one-quarter shorter than in Barcelona), but only 4 percent of the population live within 800 meters from a metro station." (Bertaud/Franklin, 2004. p15.) Data from Frumkin (2002) finds that in the same Atlanta metropolitan area, which is composed of 10 counties, the share of on-road vehicles of nitrogen oxides and hydro-carbon emissions are 58% and 47%, respectively. These are percentages that are higher than the norm. This evidence points to sprawl leading to higher emissions.

3. **Theoretical Discussion**

What is being analyzed is factors in urban sprawl and the negative externality of emission levels that come with it. In particular the opportunity costs subjected to having urban sprawl compared to compact city environments. Assuming the standard hedonic housing model, there will be an evaluation of the housings land use with the addition of emissions data to determine the proper policies to implement. By figuring the degree of emissions, there can be a forecasting determine in conjunction with population growths.

What is to be expected from reading the literature is that as suburbanization increases, or the density in urban areas stagnate or decrease, the number of emissions increases. The further the distance from the CBD, or the time used for commuting, the larger the increase in emissions. Larger increases in emissions will lead to key policy changes such as urban growth boundaries, rent controls or stricter city zoning. Determining the variables for density, emissions over a time series data submissions will indicate the level of growth margins.

The data sources being used are the U.S. Bureau of Labor Statistics (BLS), U.S. Census Bureau (CB) and the U.S. Environmental Protection Agency (EPA). While county data and higher macro level data is readily available, micro city data can be a challenge to find. The BLS supports an outstanding array of micro data for cities, specifically labor force sizes. It is even examined deeper by looking at the number of workers inside each market such as manufacturing, professional and business services and government. This project would have been impossible to create with such a resource.

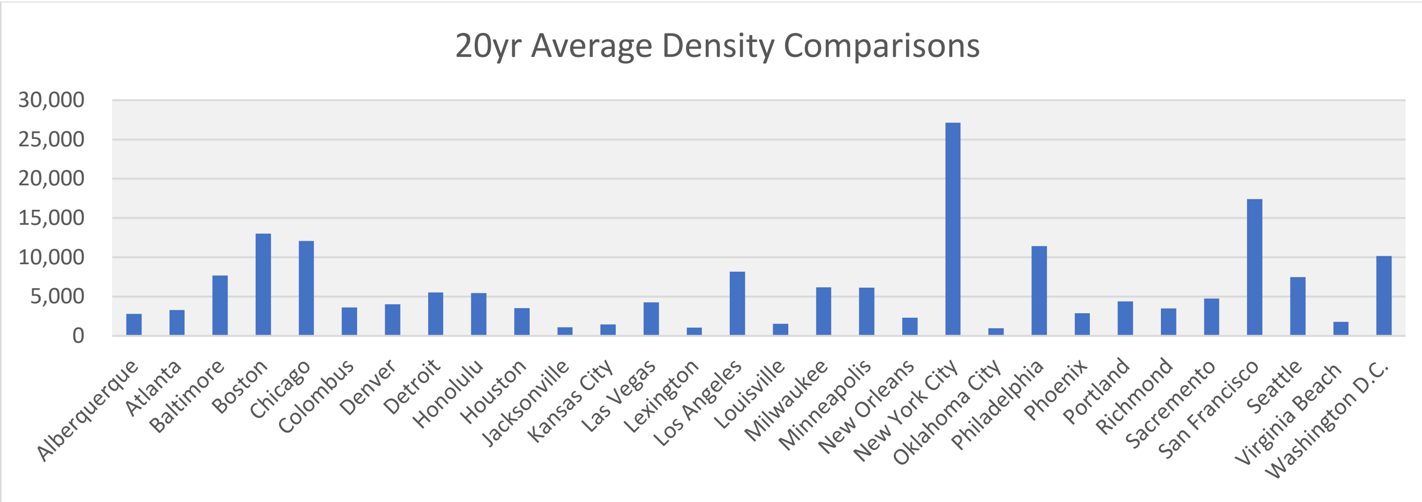
The CB hosts population data needed to decide which cities could be used and to formulate the density of the selected cities over time. Populations less than 100,000 were rejected as their population size does not have a strong enough urban sprawl effect compared to ones with greater than 100,000. Without the density data the basic model for urban sprawl could not be used.

Finally, the EPA offers AQI for cities from their many AQI stations placed across the U.S. The collection consists of $PM_{2.5}$, PM_{10}, NO_2, O_3 and SO_2 from 584 CBSA's in the U.S. spanning as far back as 1990. While unfortunate that there is yet a national database for city inventories, AQI is a valuable alternative that is available for a panel data analysis.

4. Data

City selection was based on population size being at least greater than 100,000 as a control as density in and of itself is not a reflection of city size, but volume of human beings inside a city (density is population divided by land area). Lower density cities are indications of urban sprawl while higher densities are indicators of compact cities which are used for control. This is an absolute must in the model, as indicated by the literature and data discussion, density offers a basic insight into whether a city is sprawled or compact. Figure 1 offers perspective into the variation of density sizes being examined.

Figure 1: City Density Sizes

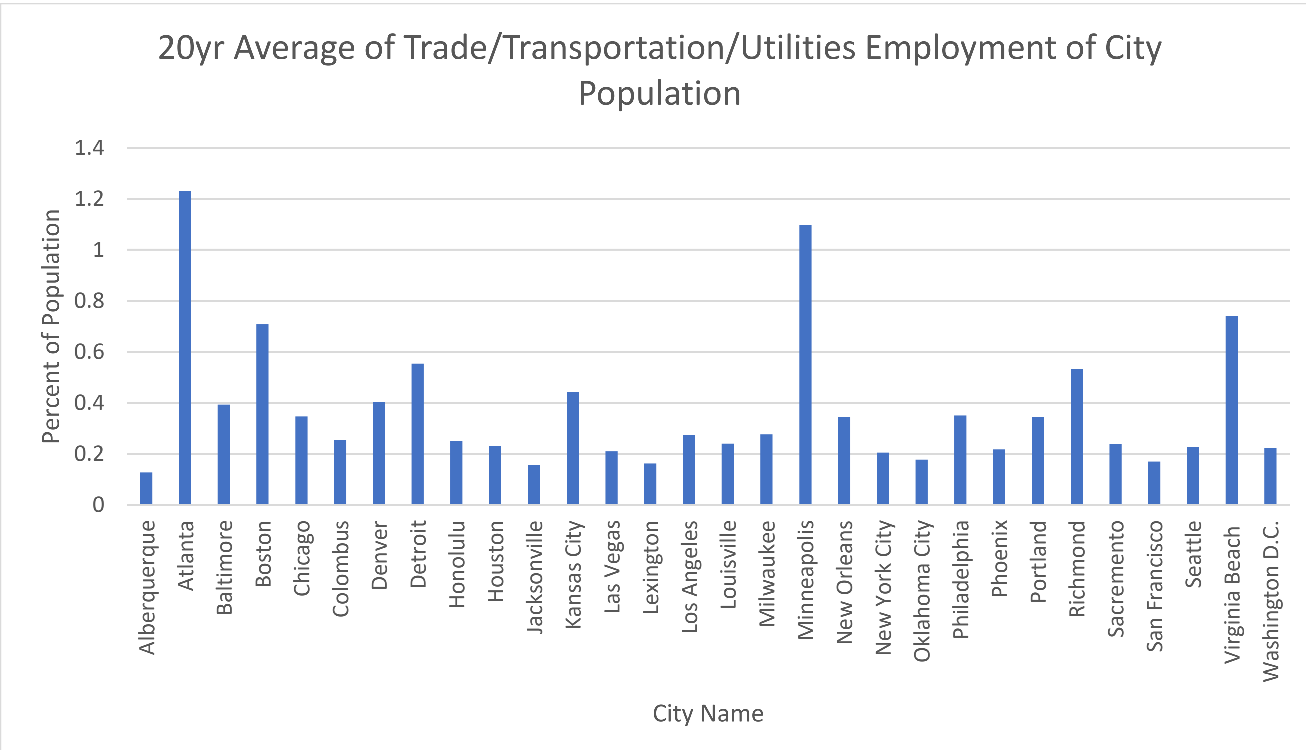


Source: U.S. Census Data

The next variable is a dummy variable, and it is whether the city has implemented an urban growth boundary (UGB). The existence of urban growth boundaries is to combat cities from becoming wide and to promote them growing tall. However, the prominence of them in the U.S. is few. The cities of Portland, Knoxville and Boulder have implemented urban growth boundaries with conflicts to varying interests.

Gathering transportation costs data can be difficult as most transportation is private, and it is not in the interest of private citizens to share their data. The BLS has employment data for the trade, transportation and utilities industries of every city and will serve for the not only the transportation costs portion of urban sprawl, but also provide an understanding of how stretched the utilities network is throughout a city. This variable is less than perfect. As said, most transportation is private and commute data provided by the CB does not stretch the necessary amount of year to be useful. As such, trade and transportation employment will theoretically cover only a portion of the vehicles that travel the roads and the inclusion of utilities employment with the trade and transportation employment could skew results. It would be preferable to have the two separated for accuracy and transparency. Figure 2 offers insight into city employment totals for the trade, transportations and utilities.

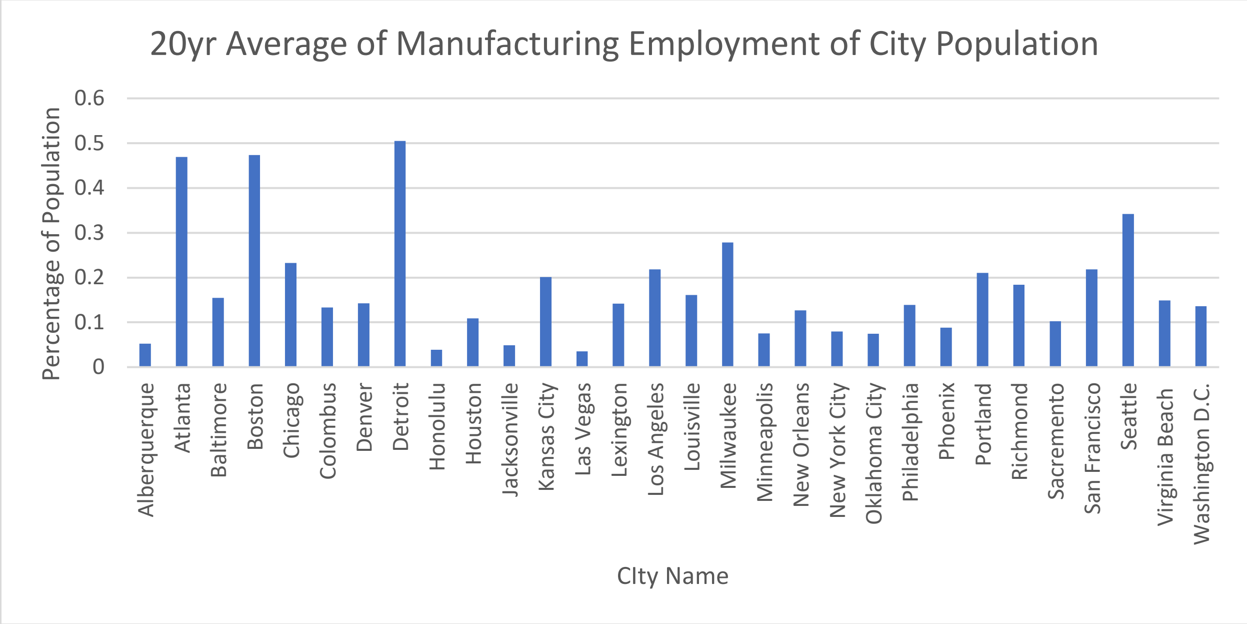
Figure 2: 20 Year Average of Trade/Transportation/Utilities Employment of City Population



Source: U.S. Bureau of Labor Statistics & U.S. Census Bureau

Much like the trade, transportation, and utilities employment BLS covers the manufacturing employment which is a control with calculating emissions caused by sprawl effects. Literature supports the use of energy through transportation and household living as the primary causes of emissions with urban sprawl. This makes sense as most if not all city models have their industry and manufacturing placed close to their CBD's to allow for shorter transportation. Figure 3 shows how much manufacturing employment as city has as a percentage of its population.

Figure 3: 20 Year Average of Manufacturing Employment of City Population



Source: U.S. Bureau of Labor Statistics & U.S. Census Bureau

BLS also hold one of the simpler metrics: Unemployment Rate. Unemployment rate is a basic universal measure of the well being of an economy is running and is useful for measuring whether local fiscal or monetary policy is effective. This runs in conjunction with the finance sector side of urban sprawl as local factors often influence unemployment in the short run.

The AQI data provided by the EPA is available for all of the 30 cities. One particulate metric is shared amongst all the annual mean for $PM_{2.5}$. This stands for particulate matter that is at 2.5 microns or less. This PM is not all to dangerous at low levels like most pollutants, but when too much of them are together then it becomes a problem. Any amount below 50 is considered safe for breathing.

GIS, or geo-spatial data mapping, has become idea for city planners as explains the data geographically visually. Without a determinate equation for urban sprawl, and even the word “urban”, a simple solution can be offered to the problem that offers a less optimal, however still effective, substitute. NASA provides satellite map visualizations for an assortment of data bases beneficial to urban economics like density, emissions and vegetation.

5. Methodology

This study begins by taking 30 cities in the united states across the years of 2000-2019, with populations greater than 100,000, and adds 6 variables to make the two models:

1. **OLS:** $\mathbf{AQI\_am_{ti} = \beta_0+\beta_1 Dens_{ti} + \beta_2 UGB_i + \beta_3 Unemp_{ti} + \beta_4 TTU\_Per_{ti} + \beta_5 pop_{ti} + \beta_6 Ind\_Per_{ti} + e}$

2. **Fixed Effect:** $\mathbf{\ln(AQI\_am)_{ti} = \beta_0+\beta_1 Dens_{ti} + \beta_2 Unemp_{ti} + \beta_3 TTU\_Per_{ti} + B_4 pop_{ti} + \beta_5 Ind\_Per_{ti} + City_i + Year_t + e}$

The reason for two models is to assist in controlling omitted variable bias between results. Running a fixed effects model narrows randomness or variance between variables such as heteroscedasticity in the results observed in the OLS. Accounting for $City_i$ and $Year_t$ in the fixed effects model will increase accuracy in the results by controlling any variable that is constant within a city overtime, but different across cities ($City_i$) and by controlling any variable that is constant within a single year for all cities, but different throughout time ($Year_t$).

AQI_am and Density are the main variables. Density, as explained, is simply population/land area. For the fixed effects model, AQI_am data was taken by its natural log. By taking the natural log (ln) of the AQI data, results will conclude with a specific amount of change and increase homoscedasticity.

Whether an UGB has been implemented by the city is the second variable. While there are not a lot of American cities with an urban growth boundary, the sole purpose of it is to negate urban sprawl. It is ideal to include the growth of borders over the years, but not enough information exists so it has been implemented as a dummy variable. The Cities examined that contain UGB's are: *Denver*, *Honolulu*, *Lexington*, *Minneapolis*, *Portland*, *Seattle* and *Virginia Beach*.

Unemployment measures any possible economic struggle stemming from issues with the local economy. As cities become too large and local governments do not correctly update their policies, the urban environment may begin to decay. Unemployment can be caused by slow economic growth, increases in population and/or falls in industry, resulting in the unemployment going up as there is not enough work available. This results in a decrease in income and, based on preference, living in cheaper housing or renting.

The TTU_Per variable was calculated by taking the BLS data of Transportation/Trade/Utilities employment and divided by their city CB population. It should be noted that the cities of Atlanta and Minneapolis exceed 100% which means that the cities labor force is not sufficient to take care of that industry and relies on commuters outside of the city population to fill the demand of the needed employment.

The ind_per variable is a control for the additional pollution sources. This variable is much like the TTU_per variable in that it is calculated by taking the overall manufacturing workforce of the city and diving it by its total population.

6. **Results**

The database used with this paper is a panel of 30 cities from the years 2000-2019. Only cities for which had data for all variables were included. The years 2000-2019 were selected because it was the most recent years for which there was data from all our sources. Figure 4 displays the parameter estimates for the simple OLS and fixed effects model. The updated model with predicted estimates of the coefficients from the OLS results are:

Upon analysis of the OLS parameter estimates it appears that Dens, UGB, Unemployment < 0 and TTU_Per, Pop, Ind_Per>0. This shows that as AQI increases Density, UGB and Unemployment decrease. Meaning lower emissions levels (the lower the AQI the better) have a negative correlation with higher unemployment, density and having an UGB while also having a positive correlation with population, industry employment percentage and trade/travel/utilities employment percentage. However, density and population both are "economically" insignificant. For every additional person added to the city population, the AQI would increase by a thousanth (.001) and for every incremental increase to a cities density, AQI would decrease by a twenty thousandth (.0002). Additionally, all variables except for TTU_Per show statistical significance with p values (**Pr > |t|**) less than .05.

For the fixed panel regression, all parameter estimates, except for unemployment, show a positive correlation with lower AQI's as the β coefficients, except for unemp, increase with the independent variable. Statistical significance unlike the OLS regression is scattered showing two, almost three, statistically significant variables. With a confidence interval of 95% the acceptable p value of a coefficient is anything <.05 which results with only the intercept and density as statistically significant and nearly pop as statistically significant. Density while significant statistically is economically insignificant. For every singular increase in a city's density, the AQI in the city increases by .0001%.

Figure 4: OLS and Panel Regression Results

	OLS PE	**Panel PE**
Intercept	9.72862*** *(0.35234)*	0.752689*** *(0.2097)*
UGB	-1.29685*** *(0.26638)*	- -
Dens	-0.000227*** *(3.044E-05)*	0.000125*** *(0.000021)*
TTU_Per	0.80819 *(0.48505)*	0.316481 *(0.2368)*
Ind_Per	10.71093*** *(1.06069)*	0.524598 *(0.3791)*
Pop	0.0009532*** *(0.0001123)*	-0.00015 *(0.000120)*
Unemp	-27.38825*** *(5.20759)*	-0.24693 *(0.3131)*
Observations	600	600
Adj R-Sq	0.2739	0.8960
F Value	38.66***	67.87***

Source: Bureau of Labor Statistics, U.S. Census Bureau and Environmental Protection Agency

As for the explanatory power of the model, or the adjusted r-square, the OLS and panel data showcase a drastic difference of 0.2739 and 0.8960 respectively. This is because of the fixed effects from the panel data and running the natural log of the dependent variable allowing for less variance in the data. Meaning that while the OLS model explains only 27% of the variation in the data, when examined through the panel data it is 90%. This indicates that the model is meaningful in explaining the relationship between AQI_am and all the other variables (minus UGB).

Finally, on examining the **Pr > F** values for both models, they both fall beneath the threshold of .05 set by the confidence interval with both matching at <.0001. Because of these results both models can accept the null hypothesis, or accept the presented models for AQI_am.

7. Conclusion

Examining the literature on urban sprawl points to facts that higher emissions are caused primarily by energy expenditures from housing and vehicles, amongst other negative externalities. Micro economical city data, while much more difficult to find compared to macro level country or even state level, seems to indicate this to be true.

Data collection from city trade/transportation/utility and manufacturing employment records from the U.S. Bureau of Labor Statistics indicate a positive correlation between lower employment and lower annual AQI's when examined over a 20-year period (2000-2019) in larger (populations>100,000) U.S. metropolitan cities. Additionally, parameter estimates from density show that as city density increases, AQI results in a very marginal decrease. OLS regression results from city limit zoning policies such as urban growth boundaries show a positive correlation as AQI decreases, indicating that zoning policies are effective in decreasing emission effects.

Setbacks from this study are the lack of city level databases. City emission inventories are non-existent except for those with massive city populations such as New York City, Chicago and San Francisco (pop>1,000,000). The U.S. Census Bureau has much state and county level timeseries data but lacks city level timeseries with an unreliable and cluttered website with some URL extensions leading to no longer existing webpages. The opposite can be said for the U.S. Bureau of Labor Statistics as their city level databases are extensive and easy to maneuver.

Finally, it should be noted that this study could be more extensive give additional time. There are plenty of additional variables that could be added to this model to strengthen its accuracy. The premise of the original model still holds regardless, emissions (AQI) are lowered as city density increases with transportation and utility services being held at minimum.

References

Bertaud, Alain and H. Richardson. “Chapter 17 Transit and Density : Atlanta , the United States and Western Europe.” (2005). https://www.semanticscholar.org/paper/Chapter-17-Transit-and-Density-%3A-Atlanta-%2C-the-and-Bertaud-Richardson/1f71a32d7713a0219038d642a41417031bded1e6

Breheny, Michael. “The Compact City and Transport Energy Consumption.” *Transactions of the Institute of British Geographers*, vol. 20, no. 1, 1995, pp. 81–101. *JSTOR*, www.jstor.org/stable/622726. Accessed 15 Feb. 2021.

Frumkin, Howard. “Urban Sprawl and Public Health.” Public Health Reports (1974-), vol. 117, no. 3, 2002, pp. 201–217. JSTOR, www.jstor.org/stable/4598743. Accessed 12 Feb. 2021.

Inmaculada Martínez-Zarzoso, Antonello Maruotti. “The impact of urbanization on CO2 emissions: Evidence from developing countries”. Ecological Economics, vol. 70, Issue 7, 2011, pp. 1344-1353,

Nechyba, Thomas, J., and Randall P. Walsh. 2004. "Urban Sprawl." *Journal of Economic Perspectives*, 18 (4): 177-200.DOI: 10.1257/0895330042632681

Sabyasachi, Tripathi, and Kaur Shupinder. “Do Negative Externalities Have Any Impact on Populations Agglomerations? Evidence from Urban India.” *Theoretical and Empirical Researches in Urban Management*, vol. 13, no. 3, 2018, pp. 5–24. *JSTOR*, www.jstor.org/stable/26472533. Accessed 13 Feb. 2021.

Wassmer, Robert W. *Urban Sprawl in Sacramento and Five Similar Regions*. Lincoln Institute of Land Policy, 2000, pp. 6–13, www.jstor.org/stable/resrep18186.5. Accessed 14 Feb. 2021.

Wu, Jianxin, et al. "Urban Density and Carbon Emissions in China." *China's New Sources of Economic Growth: Vol. 1: Reform, Resources and Climate Change*, edited by Ligang Song et al., ANU Press, Australia, 2016, pp. 479–500. *JSTOR*, www.jstor.org/stable/j.ctt1rrd7n9.27. Accessed 13 Feb. 2021.

Yasin, Muhammad. Yusoff, Mariney. Mohd Noor, Nisfariza. "Theories of Urban Sprawl." *Proceeding of The 13th International Conference on Malaysia-Indonesia Relations*, 2019. https://www.researchgate.net/publication/338278666_Theories_of_Urban_Sprawl

Appendix

SAS Codes:

OLS

```
Proc Reg data=import;
Model Aqi_am=dens pop ttu_per unemp ind_per ugb;
Run;
```

Panel Fixed Effects

```
Proc Panel data=import; Id city year;
Model Aqi_am=dens pop ttu_per unemp ind_per/fixtwo city year;
Run;
```