# Population Size vs. Number of Crimes: Is the Relationship Superlinear?

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## ABSTRACT

Do large cities suffer from an even greater incidence of crime? According to the Urban Scaling Theory, the number of crimes committed may follow a superlinear relationship as a function of the population size of city. For example, if the population size increases by 100%, the incidence of crime may increase by 120%. We analyzed a total of 11 types of crimes which had occurred in about 250 cities with more than 100,000 inhabitants in the United States during the period of 1995-2010. We found that the relationship between the number of crimes counts and the population size of cities have followed a superlinear power function without exception in all 176 cases. However, significant variations exist among the superlinear relations by types of crime. We also found that the values of scale exponents display time-invariant pattern during the 16-year period.

## KEYWORDS

Crime Counts, Population Size of City, Sublinear Relationship, Superlinear Relationship, Time-Invariant Distribution

## INTRODUCTION

Is the relationship between population size of city and the number of crimes superlinear? If so, doubling the population size of a city will more than double the number of crimes. More precisely, what is the extent of such increase in the number of crimes when the population size doubles? Do different types of crime display different patterns of increase? Also, do increasing patterns of crime vary by different time periods of analysis? These are some of the questions we try to examine in this paper. For an overall framework of analysis, we are guided by the Urban Scaling Theory, which was recently developed by urban scholars (Bettencourt et al., 2007a; 2007b; 2010; Bettencourt, 2013). The population size of cities typically ranges from hundreds to millions of people. There are many more small cities than big cities, and this scaling reflects competition for resources.

When cities are viewed as living organisms (Deckeret et al., 2000; Deckeret et al., 2007; Samaniego & Moses, 2008) or city ecosystems (Glaeser & Gottlieb 2009; Florida, 2004; Fuzita et al., 2001; Segal, 1976; Henderson, 2007), cities change shape as the population size increases. For example, the economic output and the wealth of a city grow faster than linearly. The faster superlinear growth of economic output may be due to the number of potential human interactions in bigger cities which increases exponentially. For instance, it has been suggested that the number of potential interactions

may increase as the square of the population following Metcalf's law. In short, these economic outputs may be proportional to social interactions in cities.

Thus, Bettencourt et al., (2007a) propose the superlinear scaling relation for social activities underlying the creation of wealth, productivity and ideas. For example, they have presented empirical evidence of measures that show positive impacts, such as new patents, inventors, R&D employment, and GDP to follow the superlinear relationship as a function of population size. At the same time, increasing number of social interactions from bigger cities also contributes to the superlinear relationship of those social and environmental measures, which are usually viewed as negative. They include measures, such as crime, infectious diseases, congestion, poverty, and etc. In other words, both positive and negative impacts from increasing social interactions in cities are expected to display the superlinear relationship.

On the other hand, there are other measures such as the length of road in a city, which grows slower than the increase in population size. These measures that deal with material infrastructure and network, such as the number of gasoline stations or length of electric cable, display the sublinear relation (Watt et al., 2002; Kleinberg, 2001)

Finally, another group of performance measures which increase linearly as a function of the city's population size has been identified. These measures deal primarily with needs of individuals in a city. They presented empirical evidence on such measures based on the rate of employment, household electricity and water consumption.

The general quantitative relationship between socioeconomic measures (Y), to population size of cities (N) is expressed by a simple power function of:

$$Y(t) = A \, N(t)^b \tag{1}$$

Where N (t) is population at time t, A is a constant independent of N (t), and b is the scaling exponent. When the relationship is superlinear, b>1, and when the relationship is sublinear, b<1. The linear relationship is when b=1.

The most interesting proposition is that the value of the superlinear scale exponent is approximately 1.15, whereas the value of the sublinear exponent is approximately 0.85 to 0.8. In other words, both superlinear and sublinear relations may follow a 0.15 rule which imply a 121.9 percentage increase or decrease of performance measures upon doubling of population size[1]. "Remarkably, these general increasing returns to population size manifest, on average, the same statistical relationship (the ~15% rule) across an extraordinary broad range of metrics, regardless of nation or time"[2].

However, it should be acknowledged that Bettencourt's scaling model is not fully accepted yet by academic community of social scientists for several reasons (Sahoo & Gstach, 2011; Sardasht & Saheb. 2016). Many objects the use of a simple bivariate equation to represent the dynamics of complex social phenomenon such as crime, congestion, or poverty, etc. Another reason is that the scaling model is not supported by comprehensive data analysis covering multi years and multi cities. This being the first paper, we plan to add more empirical data for comprehensive analysis, leaving the multivariate and the panel data analysis to a future paper.

Therefore, the basic objective of our research is to conduct a more detailed empirical analysis to provide further evidence to test the superlinear proposition on crime counts and city's population size that Bettencourt et al. have advanced. More specifically, we also plan to test whether .15 rule does indeed apply in the case of number of crime vs. population size.

The original empirical evidence on the number of crimes and the population size of cities provided by Bettencourt, et al. (2007A) was based only on one study on serious crimes occurring in the U.S. in 2003. They have examined the scaling relation between crime vs. population size for 287 cities using the same power function model. They have discovered the superlinear exponent of 1.16 with $R^2$ of 0.89. More recently, another study on violent crime in Brazil with the superlinear exponent of 1.2

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