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Scaling laws in the dynamics of crime growth rate

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HIGHLIGHTS

- We characterize and analyze quantitative aspects of murders in Brazilian cities.
- We find a scale behavior in the logarithmic homicide growth rates distribution.
- We find a power-law relation between the standard deviation and the initial size.

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ABSTRACT

The increasing number of crimes in areas with large concentrations of people have made cities one of the main sources of violence. Understanding characteristics of how crime rate expands and its relations with the cities size goes beyond an academic question, being a central issue for contemporary society. Here, we characterize and analyze quantitative aspects of murders in the period from 1980 to 2009 in Brazilian cities. We find that the distribution of the annual, biannual and triannual logarithmic homicide growth rates exhibit the same functional form for distinct scales, that is, a scale invariant behavior. We also identify asymptotic power-law decay relations between the standard deviations of these three growth rates and the initial size. Further, we discuss similarities with complex organizations.

1. Introduction

Methods and techniques inspired by statistical physics have been shown to be useful in the search for hidden features in social systems [1,2]. Particularly, it has been remarked that social systems can exhibit universal properties similarly to thermodynamical systems at the criticality. For example, scaling laws have been reported in scientific research [3,4], biological systems [5,6], economics [7–9] and religious [10,11] activities. In addition, there is some evidence about the relation between urban metrics and the population size, where non-linearities are explicitly manifested by power-laws [12–16]. More recently, phase transition was also found in a model for criminality [17,18].

Crime is one of the major concerns of contemporary society and, therefore, there is a great interest in understanding features of its organization and dynamics. We are living in a period when most people live in cities [19]. The increasing concentration of people in urban areas entails both opportunities and challenges [20]. In particular, cities have become one of the principal sources of problems such as pollution, spread of disease and crime [12,21]. Studies on this last subject involve many areas of knowledge going from human sciences [21–33] to exact sciences [12–18,34–40]. In particular, the economic relevance of social issues of crime has been discussed [22]. It has also been pointed out that social interactions may explain the large variance in crime in cities with different concentration of people [24]. However, despite the broad investigations

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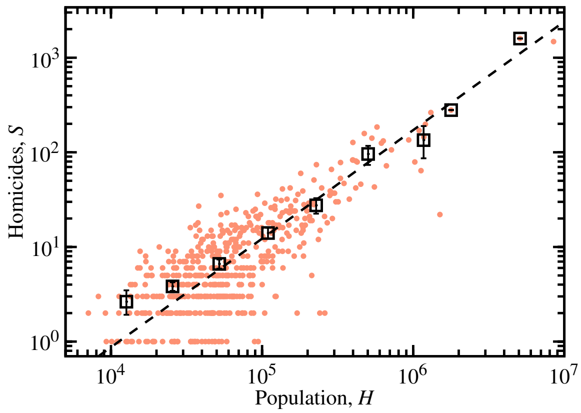

Fig. 1. The red dots are the data of the number of homicides versus the population for 528 selected cities in 1980 (on a log–log scale). The black squares are the average values of the data binned by window. The black dashed line is a linear fit of the main trend of the data on a log–log scale, where we find an exponent close to 1.15. The error bars are 95% confidence intervals obtained via bootstrapping [43]. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and the social relevance of criminality in connection with urbanization, our understanding of universality and pervasiveness of patterns in this subject remains limited. In this work, we apply a statistical approach to investigate patterns and growth characteristics of homicide.

In a quantitative manner, our study provides insights on how the growth of crime and the size of cities are related. More precisely, we study homicide growth rates in Brazilian cities based on data from 1980 to 2009 (Section 2), focusing on scaling laws related to probability distributions and standard deviations. We investigate homicide growth rates of cities aiming to understand the mechanisms that govern criminality (Section 3). We show that our results have a similar formal structure to those ones found in complex systems such as scientific research, biological systems, economic and religious activities, fact that put the universality of our findings in evidence (Section 4). Motivated by this universality, we indicate a scenario to our results in terms of stochastic models proposed in the context of complex organizations (Section 4). Our conclusions are in Section 5.

2. Data presentation

For the study of statistical properties of crime, we consider a database containing the annual number of homicides in all Brazilian cities spanning the years from 1980 to 2009, obtained from the database of vital statistics of DATASUS [41]. The annual population of cities was obtained from the demographic and socio-economic database of DATASUS [41]. In this last database, the years 1980, 1991, 1996 and 2000 report the population number obtained by the population census conducted by the IBGE [42], while all the other years are actually approximated values of the population number estimated by IBGE agency. Due to this fact, our analysis will be mainly focused on the homicides database.

We selected 528 cities from this set, which present a significant number of homicides (at least one per year) in the period from 1980 to 2009. They are about 10% of Brazilian cities but represent approximately 79% of the total number of homicides in Brazil in the period considered. Moreover, the average percentage of the population of the country living in these cities during this period is about 58%. An illustration of our database is given in Fig. 1. In this figure, a typical scaling law can be observed if we consider only the big cities (population greater than 53.465). We find an exponent very close to those found in other studies on urban metrics and crime [12–16]. However, if we take the 528 cities into account the exponent is approximately one. For years subsequent to 1980, the behavior of the exponents is similar.

In terms of the total number of homicides $S(t)$ in the year t in a given city, the annual, biannual and triannual (logarithmic) growth rates are defined as

$$R_n(t) = \ln\left[\frac{S(t+n)}{S(t)}\right], \tag{1}$$

with $n = 1$, 2 and 3, respectively. To simplify the notation, we omit the sub-index n when referring to annual growth rates, this is, we employ $R(t)$ to represent $R_1(t)$. Examples of the temporal evolution of $R(t)$ for some cities are shown in Fig. 2. They illustrate the presence of fluctuations in the homicide growth rate $R(t)$. This figure also exemplifies that the fluctuations of $R(t)$ are generally larger in small towns than in bigger urban centers. This is an expected result that motivates our analysis in the standard deviation in function of the city size, since fluctuations are larger in small systems than in bigger systems, as found in different contexts [3–9,11].