Computers, Environment and Urban Systems 45 (2014) 89–100

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/compenvurbsys

Analyzing urbanization data using rural–urban interaction model and logistic growth model

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ARTICLE INFO

Article history:
Received 22 June 2013
Received in revised form 10 January 2014
Accepted 12 January 2014
Available online 1 February 2014

Keywords:
Urbanization curve
Urbanization dynamics
Urban population
Self-organized criticality

ABSTRACT

The level of urbanization is a valuable indicator for projections of some global trends. However, urbanization levels may be based on unreliable data. This study proposes a simple method for identifying problems in the time series of urban and rural populations of a country. The time series were fitted to a rural–urban interaction population model, and improper model coefficients indicated that the time series were questionable. The upper limit of the urbanization level was calculated to determine whether the trend of the urbanization level follows the logistic growth model. An analysis of the frequency–spectrum relationship was performed to determine whether the urbanization process is a self-organized criticality and to consolidate the low possibility for chaos in the urbanization model. Empirical analyses were conducted using data from the United States, China, and India to verify data reliability and to determine the dynamical mechanism of urbanization. This is critical for demographers, geographers, other scientists, and policymakers.

1. Introduction

There are multiple indices of the urbanization of a country. The concentration index, which is related to the distribution and concentration of urban populations, is the size of the cities relative to the total population (Casis & Davis, 1946). Ledent (1980) proposed an alternative measure of urban concentration, an agglomeration index, which is based on three factors: population density, population of a large city center, and travel time to the large city center. The degree or level of urbanization is the percentage of urban population in its total population at any fixed date (Davis & Hertz, 1951). The rate or speed of urbanization refers to the change in the degree of urbanization during a period of time (Durand & Pelaez, 1965). Chen, Ye, and Zhou (2013) differentiated the urbanization curve to derive the speed of urbanization curve. To define aforementioned indices of urbanization, in addition to considering the urban proportion of the population, Arriaga (1970) also considered the size of the city where an urban population lives. The tempo of urbanization is defined as the net difference between the rate of growth in the urban population and that in the rural population (United Nations, 1974). The scale of urbanization is defined as ΣXY, where X is the proportion of the urban population in units greater than a certain size and Y is the proportion of the total population in the same units (Gibbs, 1966). The level of urbanization is a common demographic definition of urbanization because it is easy to calculate and interpret, and because of the high availability of data.

In this study, urbanization differs from exogenous urban growth. Urbanization is an increase in the proportion of a country's population that resides in urban areas, in which the city size is not considered, whereas exogenous urban growth is an increase in the number of people who live in urban areas. For example, if the urban population and total population of a country are 4,000,000 and 8,000,000, respectively, then the urban population and total population will be 8,000,000 and 16,000,000, respectively, fifty years later. Accordingly, the level of urbanization does not change, whereas urban growth increases by 4,000,000. The country is expected to reach a high urbanization level and low urban growth at the terminal stage of urbanization. Recently, much research has been conducted on urban size dynamics. Schaffar and Dimou (2012) studied the dynamics of Chinese and Indian urban hierarchies from 1981 to 2004, and examined the urban growth patterns of the rank-size relationship for cities in these countries. To eliminate problems of urban definitions, Mulligan (2006) projected the urban population above high thresholds and explored the influence of city-specific initial conditions and national-level factors on population growth. However, the proportion of urban dwellers living in large cities exhibits a substantially low correlation with the level of urbanization (Bloom, Canning, & Fink, 2008), which is investigated in this study. Urbanization has a beginning and an end. By contrast, urban growth is limitless (Northam, 1975). In current study, no cross-country analysis was

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http://dx.doi.org/10.1016/j.compenvurbsys.2014.01.002

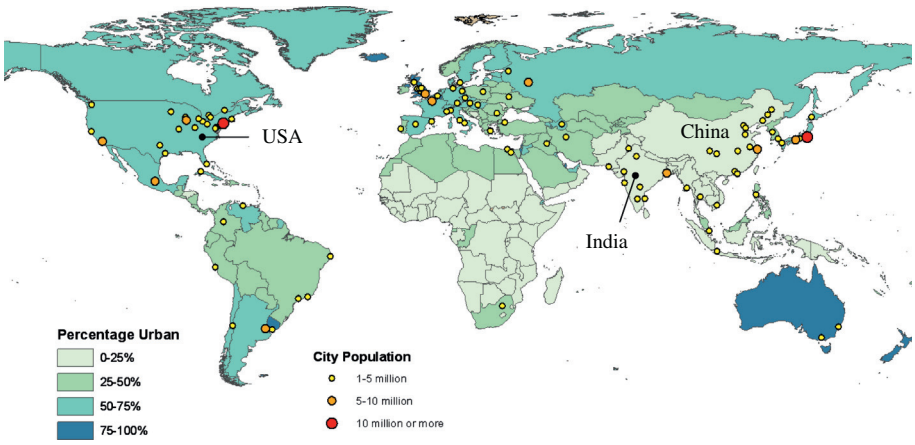

Fig. 1. Percentage of urban population and agglomerations by size class in 1960. *Source:* United Nations, 2012.

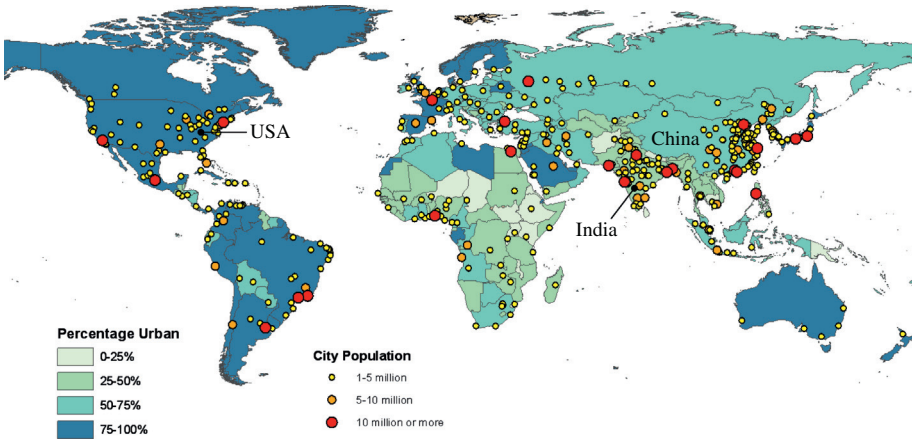

Fig. 2. Percentage of urban population and agglomerations by size class in 2011. *Source:* United Nations, 2012.

conducted using a list of cities ranked according to size for each country, as shown in Figs. 1 and 2, nor were the aggregate urbanization statuses of the regions and the world determined. Stoto (1979) indicated that the date that the forecast is made is the principal factor determining error. Keyfitz (1981) argued that comparing individual forecasters is essentially futile. This study investigated the time series reliability of the urbanization level; however, the urbanization level was not forecasted for the future and forecasting methods were not compared.

The curves of the change in the level of urbanization over time are called "urbanization curves" (Knox, 1994; Northam, 1975). The relationship between the urbanization level and various topics, namely socioeconomic development (Annez & Buckley, 2009; Black & Henderson, 1999; Bloom et al., 2008; Chenery & Syrquin, 1975; Fay & Opal, 2000; Henderson, 2003; Jones & Kone, 1996; Ledent, 1982; Njoh, 2003; Polèse, 2005; Woods, 2003), the environment and resources (Alig, 2010; Shen, Peng, Zhang, & Wu, 2012; Zhou et al., 2004), and energy consumption and emissions (Cole & Neumayer, 2004; Krey et al., 2012; Poumanyvong & Kaneko, 2010; York, 2007), has been explored extensively. Therefore, the level of urbanization has been used as an indicator for projecting various global trends, such as energy use, poverty, and environment and resource use. (Energy Information Administration, 2012; World Bank, 2011; World Resources Institute, 2003).

Currently, the United Nations (UN) is the only institution that produces projections of urban and rural population growth on a global scale. The World Urbanization Prospects (WUP) data set published biannually by the United Nations Population Division is the most comprehensive source of estimates and projections of the urban and rural populations of every country, region, and continent in the world. The published statistics follows the national census definition of urban population, which differs considerably among nations (geographical variations) and varies over time within a single country (historical variations). National definitions are generally based on demographic, administrative, economic, sociocultural, and geographic criteria (Frey & Zimmer, 2001). The UN (1974) detailed discussions on the problems of urban definitions. After discussing numerous definitional problems and the lack of reliable and current census data, Cohen (2004) concluded that nearly any statistic on an urban population is merely an approximation of reality. Bocquier (2005) indicated that the UN projections were systematically biased, and the problem primarily originated in the linear regression model used in the projection method. Montgomery (2008) also indicated that the urbanization levels were significantly overestimated in the UN projections. This problem arising from the UN projections raises obvious concerns regarding data reliability and makes cross-country comparisons problematic. Because the WUP data set is widely used and referenced, methods for identifying definition and measurement problems in the time series of urban and rural populations are required.

Time-series analyses of empirical population data have indicated that chaos is rare in natural populations (Ellner & Turchin, 1995; Upadhyay & Rai, 1997). Holland (1995) believed that the interactions that form a city are typically stable. Furthermore, by