Spatiotemporal patterns of urban sprawl and its relationship with economic development in China during 1990–2010

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ARTICLE INFO

ABSTRACT

Given the fact that China has been experiencing rapid urbanization since the 1980s, limited empirical research has analyzed the spatial patterns of urban land expansion across Chinese cities using national data sets. This article attempts to explore evidence of urban sprawl and its relationship with levels of economic development using novel geospatial data on urban area boundaries and development densities for all Chinese cities. Different from existing studies, we used a decomposition approach to examine the differences between the 1990 urban boundaries and their newly developed suburbs (1990–2010) in population density and road intersection density, two key characteristics of urban sprawl. The main results show that Chinese cities have experienced dramatic increases in built-up areas but substantial decreases in development densities in the newly urbanized areas in comparison to their inner city counterparts, signifying concrete evidence of urban sprawl. Moreover, results from regression analyses indicate that a city's economic development level was positively related to urban land expansion after controlling for confounding factors, largely due to the nature of China's land-centered urbanization and economic development strategies. Findings from this article can help raise awareness about the staggering reality of urban land expansion across Chinese cities and urge urban planners and policymakers to tighten their rural-to-urban land conversion systems and curb urban sprawl.

1. Introduction

Best-known as an American phenomenon, urban sprawl is mainly characterized by poorly planned, low-density development occurring in the fringes of cities and metropolitan areas (Bruegmann, 2006; Harvey & Clark, 1965). Urban sprawl started to lose momentum in the U.S. and other developed countries in recent decades due to the skyrocketing costs and detrimental consequences of sprawling growth (e.g., waste of farmland, environmental degradation, construction of massive infrastructure, traffic congestion, public health concerns, residential segregation, etc.) in comparison to compact development (Brueckner, 2000; Hasse & Lathrop, 2003; Laidley, 2015). However, as China rapidly urbanizes since the 1990s, numerous anecdotal observations have suggested that Chinese cities have been repeating the same mistakes of urban sprawl as American municipalities have made decades ago (Bosker, 2014; Kuang et al., 2014; Yew, 2012).

Latest research suggests that the overall growth rate of urban built-up areas nationwide has exceeded that for urban population over the last two decades (Gao et al., 2016; Kuang et al., 2016; Ma, He, & Wu, 2016). Rampant urban development has occurred in the outskirts of virtually every city and town, encroaching into precious farmland that is extremely important for sustaining China's large population. More appallingly, a massive construction boom across the country in recent years has left abundant housing, factories, commercial facilities, and new urban districts with inexcusably low occupancy rates, known as 'ghost cities/towns' (Campanella, 2012; Day et al., 2013; Hsing, 2006; Liu & Salzberg, 2012; Yue, Zhang, & Liu, 2016).

Dramatic urban land expansion in China is not only driven by economic development and market forces as it is in the United States and other Western countries (Barry, 1980; Brueckner, 2000; Deng et al., 2010; Tian, Ge, & Li, 2017; Zhang, 2000), but also attributable to government planned urbanization (Fang & Pal, 2016). Unprecedented rapid economic growth, rising incomes and massive rural-to-urban migration in China inevitably incur immense increase in urban built-up areas and push urban boundaries outward. However, it is also non-negligible that the loose rural-to-urban land conversion system in China

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has made urban land expansion or converting agricultural land in urban fringes to urban use (e.g., industrial or commercial) become a lucrative means for local governments to collect a significant proportion of municipal revenues (Lin, 2007; Tian et al., 2017). While China's national government repeatedly enjoined local governments to tighten up the rural-to-urban land conversion procedure and preserve farmland, it has been a prevalent practice for municipal governments to misuse their power by leasing superfluous land to developers (Tian & Ma, 2009; Zhang, 2000). A nationwide real estate or construction boom aforementioned is largely due to the high degree of dependence on land financing and land-centered urbanization policies adopted by fragmented local governments across China (He, Huang, & Wang, 2013; Schneider & Mertes, 2014; Ye & Wu, 2014b; Zhang, 2000).

While an increasing number of studies in recent years have explored the spatial and temporal patterns of urban sprawl in China, most research examined urban area expansion in individual cities, especially those metropolises in the most developed eastern coastal region (Schneider, Chang, & Paulsen, 2015; Yue, Liu, & Fan, 2013; Zhang & Su, 2016; Zhang et al., 2005). To date, less research has systematically investigated patterns of urban sprawl throughout China utilizing national data sets (Gao et al., 2016; Kuang et al., 2016; Ma et al., 2016). Given the fact that scholars have addressed the colossal gap between China's eastern coastal areas and their inland counterparts (Fang, Li, & Wang, 2016; Wei, Li, & Yue, 2017; Zhao et al., 2015), with enormous regional disparities in levels of development and urbanization across China, in-depth studies of urban sprawl using nationally representative data are much needed (Huang et al., 2015; Wei et al., 2017).

Another gap in the existing literature on urbanization in China is a lack of research that tests whether Chinese cities have followed a sprawling path of development in comparison to their characteristics in 1990. For example, numerous studies of urban sprawl in the U.S. have suggested that low-density and poor transportation connectivity are the hallmarks of urban sprawl (Ewing, Pendall, & Chen, 2003; Galster et al., 2001). However, little empirical research has used such indices to investigate if newly constructed suburbs in Chinese cities are significantly less compact than their earlier form in the 1990s. One exception is that Jiao (2015) quantified a city's degree of sprawl by comparing the growth rates of the urban core and its suburbs. However, one limitation of this study is that the distributions of population and other development such as road network were not taken into consideration. Another research ranked the degree of urban sprawl across Chinese cities using an index that normalizes each city's amount of urban land expansion by its population growth rate (Gao et al., 2016). Based on this measure, Gao et al. found that small and medium cities in western China have experienced the highest degree of sprawl. While the use of such population-standardized index helps reveal the imbalance among different regions, it dramatically overestimated the degree of urban sprawl in China's inland cities but underestimated that for coastal cities because of a massive inflow of migrants from the inland to coastal regions (Campanella, 2012; Fan, 2005; Zhang & Song, 2003).

The third limitation of the existing literature is that scholars have extensively explored the driving forces of urban land expansion, especially how urban sprawl has been driven by economic growth and land use and urban planning policies (Liu, Zhan, & Deng, 2005; Ma et al., 2016; Tian et al., 2017; Ye & Wu, 2014a), but little research has investigated how urban sprawl affected economic development. In light of the China's unique "land financing" and rural-to-urban conversion system that has created rampant fervor of achieving economic growth goals through "land-centered" urbanization (Ye & Wu, 2014a), it has implications to analyze to what degree a city's economic development was attributable to urban land expansion using national datasets.

Built on the existing literature, this article attempts to investigate the characteristics of urban land expansion (1990–2010) in China and its relationship with economic development levels using more reasonable measures and novel geospatial data sets. We began with an analysis of the spatial and temporal patterns of urban land expansion

among Chinese cities by mapping the relative and net increase of urban land between 1990 and 2010, and then examined the differences between old urbanized areas (i.e., 1990) and their newly constructed suburbs (i.e., post-1990) in population density and density of road intersections. Last, we applied regression methods to explore whether a city's economic development level was positively associated to its magnitude of urban land expansion after accounting for other confounding factors.

2. Data and methods

Data for this empirical research were obtained from the following four sources. First, urban area boundaries in geographic information systems (GIS) format for all Chinese cities in 1990 and 2010 were acquired from Wang et al. (2012), who extracted impervious areas or urban built-up areas of all 663 cities in China from both Landsat TM/ETM + satellite imagery and high spatial resolution Google Earth images. The extensive spatiotemporal coverage of this dataset allows us to examine nationwide patterns of urban sprawl. Using remote sensing derived data on urban areas has become a common practice in spatial analysis of urban sprawl in recent decades (Imhoff et al., 1997; Ryznar & Wagner, 2001; Weng, 2012). Furthermore, using remote sensing techniques to estimate urban area boundaries helps address the undercounting problem of illegal or unauthorized developments, which have been widespread across China's cities and towns and is often overlooked by government collected data (He et al., 2013; Lin & Ho, 2005).

Different from most studies that relied on government released census data, to explore evidence of urban sprawl among Chinese cities, we used gridded data on population and road transportation connectivity. High spatial resolution data on population (100 m × 100 m) were obtained from Gaughan et al. (2016), who disaggregated China's county-level census data in 1990 and 2010 into fine gridded population datasets using a nuanced dasymetric mapping approach. Because traditional census data are aggregated to municipal or urban district boundaries, which hardly match the geographic extent of urban land expansion in reality, the use of fine gridded population permits us to examine seamless patterns of population distribution across the old and newly urbanized areas within a single city (Gaughan et al., 2016), thus facilitating a more accurate diagnosis of urban sprawl. Likewise, a national dataset of density of road intersections with a spatial resolution of 200 m × 200 m was acquired from the Chinese Ordinance Survey in 2013 (Long, Shen, & Jin, 2016). This dataset allowed us to examine disparities in transportation network between old and newly constructed suburbs.

Additionally, city-level socioeconomic data, including per capita gross domestic product (GDP) in 2010, cumulative amount of government investment in fixed assets, foreign direct investment (FDI), and real estate investment during 1990–2010, and percent of urban population were acquired from the China City Statistical Yearbooks published by the National Bureau of Statistics of China (1990–2010). Based on above data, our analyses on evidence of urban sprawl and the relationship of urban land expansion and economic growth among Chinese cities were carried out in three phases:

2.1. Mapping urban land expansion among Chinese cities between 1990 and 2010

First, the *Erase* function in ArcGIS 10.5 was used to extract newly urbanized areas in each city by overlaying the national data sets of the 1990 and 2010 urban area boundaries in a GIS environment. Second, we used both relative growth rate and net increase in built-up area to estimate the magnitude of urban land expansion for each city during the period 1990–2010. The use of growth rate or percentage increase in urban area provides a standardized measure of urbanization among different municipalities; however, it has a bias toward small cities.