Ecological Indicators 77 (2017) 185–193

Contents lists available at ScienceDirect

Ecological Indicators

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

Short Communication

Examining the relationship between urbanization and the eco-environment using a coupling analysis: Case study of Shanghai, China

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ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form 6 January 2017
Accepted 18 January 2017

Keywords:
Urbanization
Eco-environment
Coupling coordination degree
Shanghai

ABSTRACT

As a key issue in China's urban development, urbanization creates increasing pressure on the environment. Thus, a better understanding of the relationship between urbanization and the eco-environment is necessary for Chinese policy makers to realize sustainable urbanization development. Making reference to physical coupling models, we developed a coupling coordination degree model in order to examine the relationship between urbanization and the eco-environment in Shanghai, using data from 1980 to 2013. The comprehensive level of Shanghai's urbanization process during the study period was estimated using an index composed of four primary indicators, namely: demographic urbanization, spatial urbanization, social urbanization, and economic urbanization. We also developed an index system for the eco-environment, which was based on four primary indicators: the environmental level, eco-environmental endowment, eco-environmental pressure and eco-environment response. The entropy method was subsequently employed in order to identify the contribution made by each indicator to the compound system during the study period. The results show that: (1) economic urbanization and eco-environmental response made the greatest contributions to the urbanization subsystem and the eco-environmental subsystem, respectively—these are thus the key factors to consider in policy decisions aiming to adjust the coupling coordination degree between the two subsystems; (2) the two parameters α-urbanization and β-eco-environment were found to have minimal effect on the coupling coordination system; (3) the coupling coordination between urbanization and the eco-environment produced an S-shaped curve, and both subsystems were found to have evolved from seriously unbalanced development at the start of the study period into superiorly balanced development at the close of the study period. The results of this study hold important implications for efforts to achieve the coordinated development of both urbanization and the eco-environment.

1. Introduction

More than half of the world's population now lives in cities, and this proportion is growing rapidly. Millions of people move from rural areas to cities every year, and urban areas are sprawling at even faster rates than their populations are growing, a development that is leading to increased pollution and emissions levels (Wang, 2014; Liu et al., 2014). The choking pollution and other environmental problems that have resulted from these shifts are in turn harming urban health (Guan et al., 2014). While the majority of the world's city dwellers lived in developed countries in the 1950s, the largest and fastest growing cities are now located in developing countries—especially in China (Liu et al., 2015). While China's gradual transition toward an urbanization-oriented development strategy has generated spectacular results, delivering an average annual growth rate of 0.93% over the past three decades (Wang et al., 2014a; CSY, 2014), serious challenges have become apparent in relation to that growth, including the population explosion, resource scarcity, and eco-environmental deterioration (Li et al., 2012; Wang et al., 2014b; Zhao and Wang, 2015). China's

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http://dx.doi.org/10.1016/j.ecolind.2017.01.017
1470-160X/

rapid urbanization, which has been accompanied by high-speed economic growth, has also led to a range of environmental issues (Wang et al., 2015b). According to Northam's division of the process of urbanization, China currently occupies a stage of urbanization classified as "accelerated development" (30%–70%) (Northam, 1975). Given that the country has not yet completed the historical tasks of industrialization and urbanization, the "accelerated" urbanization levels currently being seen in China are predicted to rise for many years to come (Fang et al., 2015). Methods must be developed to enable this rapid development to occur in a sustainable manner that maintains a good quality of life for China's population. The coordination of urbanization and the ecological environment ("eco-environment") is critical to this task.

Most previous research addressing the relation between urbanization and the eco-environment has focused on measuring the "Environmental Kuznets Curves (EKC)," a nonlinear relationship which can be used to describe the urbanization-environment system (Fang and Wang, 2013; Ding et al., 2015). The Environmental Kuznets hypothesis was first proposed by Grossman and Kreuger (1994) to describe the relationship between development and environmental quality; the EKC posits the existence of an inverted U-shaped relationship between development and the environment, implying that whilst levels of environmental quality first decrease with economic development, they subsequently increase in line with rising development levels. Since the work of Grossman and Kreuger (1994), a growing body of literature has used various quantitative techniques to test the hypothesis between urbanization and a range of eco-environmental indicators (Liu et al., 2007, 2011). The empirical results, however, are mixed. For example, using the ARDL approach, Al-Mulali et al. (2016) found the EKC hypothesis to hold when examining the relationship between urbanization and air pollution in Kenya. A similar study was also undertaken by Park and Lee (2011); whilst they did not find a single dominant EKC shape in the relationship between economic development and SO_2, or between economic development and NO_2, they did however locate a dominant U-shaped curve in the relation between development and CO. Martinez-Zarzoso and Maruotti (2011) demonstrated the existence of an inverted U-shaped link between urbanization and CO_2 emissions in developing countries. However, using a semi-parametric panel data model, Zhu et al. (2012) found little evidence to support an inverted U-shaped curve between urbanization and CO_2 emissions—this empirical study refuted the Kuznets hypothesis in 20 emerging countries. In addition, using the fixed effects and the generalized method of moments, Al-Mulali et al. (2015) provided evidence for the existence of an inverted U-shaped relationship between ecological footprint and gross domestic product (GDP) growth in upper-middle- and high-income countries, although not in low- and lower-middle-income countries.

In recent years, Chinese scholars have begun to study the theoretical relationship between urbanization and the eco-environment (Wang et al., 2014b; Fang and Wang, 2013). For instance, Huang and Fang (2003) have argued that an interactive coercing relationship exists between urbanization and the eco-environment. This relationship can be described in the form a double-exponential curve (Wang et al., 2014b). The interactive coercing analysis of the relation between urbanization and the eco-environment has generated a comprehensive understanding of the nonlinear relationship between the subsystems of the urbanization-environment compound system. The influence of urbanization on urban development intensity (Wang et al., 2015b), water resources (Bao and Fang, 2007), energy use (Wang et al., 2016a,b, 2017), land use and land cover change (Fu and Weng, 2016), $PM_{2.5}$ emissions (Han et al., 2014), solid waste emissions (Wei et al., 2015), water vulnerability (Srinivasan et al., 2013), and ecosystem-service values (Estoque and Murayama, 2013; Li et al., 2016) have all been analyzed quantitatively and qualitatively with reference to interactive coercing theory. Overall, scholars from various countries have begun to pay more attention to the coordination of urbanization and the eco-environment, as well as the sustainable use of environmental resources, in order to ensure high living standards (Wan and Wang, 2014). However, in general, all of the empirical studies that have investigated the relationship between urbanization and the eco-environmental indicators have been based on the Environmental Kuznets Curve hypothesis. Despite these advances, a lack of understanding remains with respect to the coupling relationship between urbanization and the eco-environment.

Examination and quantification of the coupling process between urbanization and the eco-environment is crucial for the realization of sustainable and healthy forms of urbanization. Coupling, a phenomenon in which two or more indicators impact on each other through various interactions, originates in the field of physics (Li et al., 2012). The technique has been used widely in the field of climate change, but has seldom been employed in examining the relationship between urbanization and the eco-environment, despite being the available technique for conducting such analyses (Wang et al., 2015a). Given the pace of China's urbanization, environment issues relating the expansion of cities are most evident in fast-growing urban areas, triggering scholars of sustainable urbanization in China to attempt finer-scale analyses at the megacity level. As China's powerhouse for the past three decades, Shanghai is representative of a fast-growing urban area, and it was thus selected as the study area for the present investigation of the coupling relationship between urbanization and the eco-environment.

Drawing on the physical coupling model, we developed a coupling coordination degree model that would enable us to extend existing scholarly understandings of the relationship between urbanization and the eco-environment. The coupling coordination degree model developed in this study makes possible an analysis of the dynamic coupling process that occurs between urbanization and the eco-environment in a context of rapid economic growth. This research intends to fulfill three primary objectives. First, this paper aims to reveal the dynamic trends present in the degree of coupling between urbanization and the eco-environment, using data on Shanghai in the period 1980–2013. Second, we aim to evaluate the respective contributions made by a range of selected (primary and secondary) indicators to the urbanization subsystem and the eco-environment subsystem, using the entropy method to identify those indicators that make the greatest contribution to the two systems. Identifying these indicators is an important task in providing a knowledge base for the coordination of urban development and environmental protection in decision making and policy formulation addressing environmental quality in the face of changes in the urbanization level. Thirdly, the study provides of an analysis of the effects of changes in the parameters of the model on the degree of coupling.

The rest of this study is organized as follows. Section 2 focuses on methodology and materials. A description of the study area and the steps taken to establish the coupling coordination degree model are presented in this part. Results and discussion are then presented in Section 3 and the conclusions and policy implications of this paper are summarized in Section 4.

2. Materials and methods

2.1. Study area

Located on China's central eastern coast, at the mouth of the Yangtze River, Shanghai is administered as a municipality with province-level status (Fig. 1). It is one of the largest cities in China