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Investigation of a "coupling model" of coordination between low-carbon development and urbanization in China

Qijiao Song[a,b], Nan Zhou[c], Tianle Liu[a], Stephanie A. Siehr[c,d], Ye Qi[a,*]

[a] School of Public Policy and Management, Tsinghua University, Beijing 100084, PR China
[b] School of Management, Capital Normal University, Beijing 100048, PR China
[c] China Energy Group, Energy Analysis and Environmental Impacts Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, United States
[d] Department of Environmental Science, College of Arts and Sciences, University of San Francisco, United States

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ABSTRACT

Based on data from 30 provinces in China, this paper builds a coordination degree model and a coupling coordination degree model (CCDM) for a carbon emission-urbanization system (CUS) that explores how to achieve low-carbon development during a rapid urbanization phase. Scenario analyses and case study were applied to illustrate the results, which show five basic conclusions. 1) Low-carbon development doesn't require eliminating energy consumption completely during urbanization 2) The average level of urbanization is relatively low owing to the large disparities among provinces and the provinces' economic development. Though the development of low-carbon in the 30 provinces is generally rapid, the gap between the highest provinces and the lowest provinces is relatively large because of their different socio-economic features. 3) Much more attention should be paid to CO_2 emissions per capita. The quality of public social service,the basic and medical insurance coverage for the elderly, the community service coverage in infrastructure and the green design during urban construction should be improved. 4) The coordination of CUS is closely related to the different development stages and geographic locations of each province. 5) For different types of provinces with different degrees of coupling coordination,there is a need to explore different development directions.

1. Introduction

Low-carbon development and urbanization are increasingly important issues in the field of climate change. Low carbon development is a mode of development which aims to achieve a low carbon economy through a process of de-carbonization, while contributing to sustainable development and tackling climate change (Feng, 2015). Urbanization can facilitate modernization. It sustains agricultural development and the expansion of domestic demand. It also contributes to industrial upgrading as well as coordinated regional development. The urbanization in this paper refers to the new urbanization, which lead to more scientific layout and cleaner environment than the traditional urbanization. The rapid pace and intensity of urbanization, along with the urgent need for reducing carbon emissions (i.e., the greenhouse gases carbon dioxide (CO_2) and methane (CH_4)), has raised attention to these issues in academic and government circles, particularly in China. It is essential to explore methods to keep this rapid development sustainable, maintaining a high quality of living by coordinating urbanization and low-carbon development at the same time (Li et al., 2012). As a result, this paper, which analyzes recent trends in low-carbon development and urbanization in China, aims at exploring how to achieve a win-win situation between low-carbon development and urbanization. China's *National New Urbanization Plan* (2014–2020), promulgated March 27, 2014, defines the basic principles of a new type of urbanization as "ecological civilization—green and low carbon," and it proposes a new urbanization evaluation system. Urbanization, along with lifestyle changes of urban dwellers in China, has led to a substantial increase in both energy consumption *per capita* and greenhouse gas emissions in absolute terms. The consequence is that the urban environment is also facing increasing pressure from it. In addition to direct energy consumption by growing urban populations, the related construction, transportation, and industrial production are using high levels of energy and contributing to higher concentrations of GHG in the atmosphere (Guo et al., 2010).

Different patterns of urbanization yield varying levels of carbon emissions. In appropriate or inefficient urbanization practices result in

* Corresponding author.
E-mail address: qi@tsinghua.edu.cn (Y. Qi).

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higher carbon emissions (Gu et al., 2009). Thus it is crucial to develop a scientific method for evaluating how urbanization practices can minimize energy use and carbon emissions. This paper evaluates case studies from 13 municipalities in Jiangsu Province, evaluating five aspects of urbanization: economics, spatial patterns, population, lifestyles, and quality of life (Ou et al., 2004). In doing so, Han et al. 2009) examined the index of urbanization quality,which includes economic development, infrastructure, employment, citizen life, social development, environment, land use quality, innovation quality, and urban-rural income gap. The *National New Urbanization Plan* strongly promotes aggressive urbanization policy, supporting and encouraging sustainable development, by providing best practices for the environment of low-carbon urban centers. This effort shows the current Chinese government's focus on achieving sustainable development, finding a way to use low-carbon development in the trend to urbanization. In 2009, Zhilin Liu provided a new model of sustainable urbanization for China, which integrated both elements of low-carbon economy and low-carbon society (Liu et al., 2009). Boqiang Lin and Xilin Liu also made amendments to Kaya identity (an identity stating that the total emission level of the greenhouse gas carbon dioxide can be expressed as the product of four factors: human population, GDP per capita, energy intensity, and carbon intensity) by introducing the effect of urbanization to the factors affecting carbon dioxide emissions in the current development stage (Lin and Liu 2010).

Low-carbon development is necessary to offset the negative impacts of increased urbanization in China. Theoretical and empirical works in the past do not reach a solution/conclusion about the relationship between low-carbon development and urbanization. This paper seeks to fill this research gap by using 2013's China province-level dataset. First of all, this article has theoretically enriched the relationship between urbanization and low-carbon development. Most of the existed researches paid more attention to the relationship between the speed of urbanization and the amount of carbon emissions, while urbanization and low-carbon development need more attention on quality. This paper is based on the quantitative evaluation of the relationship between urbanization level and low carbon development level, which are more scientific. Secondly, this paper uses the CCDM model to calculate the relationship between the low carbon development level and the urbanization level, which is the first use of CCDM methods for research on low-carbon development and urbanization. Thirdly, the evaluation of the urbanization level in the past is based on the individual influencing factors, this article, which use evaluated criteria in the 2014 *National New Urbanization Planning* for urbanization assessment, is relatively objective and scientific. And for the evaluation of low-carbon development level, the previous study had some shortages. For example, some studies were only focus on carbon intensity and energy intensity but ignore the economic factors (Zhu, 2010), some had more variables and incomplete data (Ma and Luo, 2011), and some used expert scoring method to determine the subjective weight of the index (Chen, 2016). And this article use LBNL indicators, can clearly reflect low-carbon development level in transportation, construction, industry, and society, and effectively avoid the above problems. To sum up, this article expands the current research of the relationship between low-carbon development level and urbanization level from the theoretical and methodological index system construction.

“Coupling,” a phenomenon originating in the physical sciences, is when two or more systems influence each other through various interactions. Coupling is now widely used in studies of climate change and urbanization (Li et al., 2016, 2012). Additionally, empirical studies have focused on the nonlinear relationship between urbanization, environmental Kuznet curves (EKC), and the environment. However, a lack of data is an obstacle for research on the relationship between carbon emissions and urbanization, especially in China.

The coupling coordination degree model (CCDM) proposed in this study was designed to: 1. reveal the current average development level of carbon emissions and urbanization in the 30 provinces; 2. identify the indicators which made the greatest contribution to the two systems in the CCDM, balancing low carbon development and urban development during macro policy-making to increase carbon emission and urbanization quality rather than the rate of urbanization; 3. evaluate the current level and development of the coupling of low carbon and urbanization; 4. explore different influences on the parameters of the coupling model in different provinces.

2. Data and methodology

Many researchers have studied the urbanization index system and presented different evaluated indicators. Using three indicators from the index—systemic, integrity, and availability of data—Zenglin Han and Tianbao Liu evaluated urbanization quality from 10 aspects, such as economic development, infrastructure contribution, employment, urban residents’ living, social development, ecological environment, land quality, innovation quality, and coordination of urban and rural (Han and Liu, 2009).

Here, according to the quantitative indicators , an indicator system that can measure the quality of urbanization, outlined in *National New Urbanization Planning* (2014–2020), this study evaluated indicators including demographic aspects (urbanization rate), public social services (unemployment rate, basic pension insurance coverage in urban resident population, basic medical insurance coverage in urban resident populations), infrastructure (public transportation accounts for the largest proportion of transport, urban public water supply coverage, urban sewage treatment capacity, living garbage treatment capacity, urban households broadband access broadband subscribers, community service coverage), and environment (urban green land share, urban construction land *per capita*). Entropy value for each index was used to determine an urbanization score. Considering the suitability and availability of data, the unemployment rate rather than the compulsory education and basic vocational skills training coverage of migrant workers’ children is used in our paper. Because there is no index data at the provincial level for affordable housing, renewable energy consumption, and green buildings, and alternative indicators were not identified, these are not mentioned in the evaluation system.

Many domestic and foreign researchers have measured Chinese low-carbon development using various index systems. For example, the low-carbon city index system (LCCC) (Chinese Academy of Social Science, 2013) contains five major categories and 15 indicators that can measure low-carbon development, including aspects such as economy (carbon productivity, energy intensity and decoupling index), energy (non-fossil energy proportion, renewable energy consumption *per capita* and carbon energy intensity), establishment (public buildings’ carbon emissions per unit of area, public transport accounts), environment (air quality, urban public water supply, forest coverage), and society (income ratio between urban and rural residents, carbon emissions *per capita* and urban low-carbon management system).

Due to the availability of data at the provincial level, this article used the evaluation system created by the Lawrence Berkeley National Laboratory (LBNL)(Zhou et al., 2012; Zhou et al., 2015; Zhou and Williams, 2013). The index of low-carbon development system and urbanization system. The system has a clear vision of what defines a low carbon development. Those selected indicators reflect the connection to different low carbon vision: economy (energy consumption per unit of gross domestic produce or GDP), population (CO_2 emissions *per capita*), residence (residential final energy), commerce (commercial final energy), industry (industrial final energy), transportation (transportation final energy) and electricity (CO_2 per power produced). They are based on data availability and given consideration of local situation. They are embedded to the governance structure and institutional capability so the implementation is not only possible but also sustainable. With careful examination and detailed comparison, we use a comprehensive, comparable, and adaptive indicator system which developed by LBNL to evaluate the low carbon development.