Ecological Indicators 94 (2018) 357–366

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Improved coupling analysis on the coordination between socio-economy and carbon emission

Liyin Shen[a], Yali Huang[a,*], Zhenhua Huang[a], Yingli Lou[a], Gui Ye[a], Siu-Wai Wong[b]

[a] School of Construction Management and Real Estate, International Research Center for Sustainable Built Environment, Chongqing University, Chongqing, China
[b] Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China

ARTICLE INFO

Keywords:
Socio-economy
Carbon emission
Coordination assessment
Traditional CCD model
Improved CCD model

ABSTRACT

Effective evaluation on the coordination between socio-economy (V) and carbon emission (W) is essential for sustainable urban planning, and this study introduces an improved coupling coordination degree (CCD) model for conducting such evaluation. The limitation of the traditional CCD model has been examined. The effectiveness of the improved CCD model is demonstrated with its application in 30 case provinces of China by using the data collected for the period 1995–2015. The results show that: (1) The subjectivity embodied in the traditional CCD model in analyzing the coordination between V and W significantly distorts the true coordination between the two systems. (2) The improved CCD model is effective as its application can reflect the reality of the sample cases. (3) The average coordination degrees of the 30 case provinces for the surveyed period show an upward evolution, and the coordination statuses of these provinces have been transforming from low-grade symbiosis to high-grade symbiosis. (4) The spatial distribution of coupling coordination degree in China is characterized by a higher degree of coordination in the Eastern provinces. The results of applying the improved coupling coordination degree model can help decision makers formulate effective sustainable measures to balance socio-economic development with carbon emission reduction.

1. Introduction

Socio-economic development has made a great revolution in humans' history. However, it has also incurred high environmental prices evidenced by climate change probably due to the extensive carbon emission (Liu et al., 2015). According to IPCC (2007), carbon emission has grown from 21 GT to 38 Gt between 1970 and 2004, increasing by 80%. Such accumulated carbon emission has contributed to warming the whole earth and exerted negative influence on human and ecology systems. Handmer et al. (2012) estimated that the annual economic losses worldwide caused by climate-related disasters have ranged from a few billion dollars in 1980 to above $200 billion in 2010. It was reported by Noy and Cavallo (2010) that nearly three million people were killed from natural disasters for the period of 1970 to 2008 in the regions of Asia-Pacific, Latin America and Africa. It is therefore considered imperative to analyze the interaction between socio-economy and carbon emission systems.

Previous studies have appreciated that socio-economic development has strong interaction with carbon emission (Wei et al., 2015; Mladenović et al., 2016). On one hand, socio-economic development relies heavily on the energy consumption, especially fossil energy consumption (Wang et al., 2017c). The carbon emission from fossil energy consumption has been accounting for more than 95% of global carbon emission since industrialization (Wang and Ye, 2016). On the other hand, the accumulated carbon emission accompanied by socio-economic development can induce economic loss and threaten the health and welfare of human beings (Lu et al., 2010). The estimated social cost of carbon (SCC) in America rose from below $5 million to beyond $15 million from 2008 to 2013 (Pizer et al., 2014). It appears that there is significant unbalance between the promotion of socio-economy activities and carbon emission control. The need for balance between the two actions is obvious, which is in line with the principle of sustainable development, as appreciated widely (Sachs, 2004; Dincer, 2011; Griggs et al., 2013). This highlights the importance of adequate understanding whether there is a coordination between carbon emission and socio-economy systems, which can help define a clear goal for guiding the two systems towards sustainable development.

Nevertheless, the accurate assessment on the level of coordination between carbon emission and socio-economy development can only be

* Corresponding author.
E-mail addresses: shenliyin@cqu.edu.cn (L. Shen), ylhuangyl@cqu.edu.cn (Y. Huang), 20150302017t@cqu.edu.cn (Z. Huang), 20160302057t@cqu.edu.cn (Y. Lou), ivy.sw.wong@polyu.edu.hk (S.-W. Wong).

https://doi.org/10.1016/j.ecolind.2018.06.068
Received 19 January 2018; Received in revised form 9 May 2018; Accepted 29 June 2018
Available online 10 July 2018
1470-160X/

ensured if the tool used for the evaluation is effective. Without an effective analysis tool, the assessment results may be misleading in designing policies for socio-economy development and carbon reduction (Zhao et al., 2016). Therefore, the aim of this study is to introduce an alternative assessment tool, an improved coupling model, for examining the coordination level between carbon emission and socio-economy development.

The rest of this paper is organized as follows. Section 2 presents literature review. Section 3 introduces research method, which is the improved coupling coordination degree model. Section 4 presents the results from applying the introduced model in 30 provinces in China. Section 5 presents discussions on the validity of the improved coupling coordination degree model introduced, followed by conclusions in Section 6.

2. Literature review

Environment Kuznets Curve (EKC) is a widely-referred hypothesis to examine the relationship between socio-economic growth and carbon emission (Gill et al., 2017). The hypothesis explains that during early stages of socio-economic development, the growth of socio-economy will result in an increase of carbon emission until the emission reaches to a peak. This relationship is also called inverted U-shaped relationship. Some researchers have demonstrated the existence of the inverted U-shape relationship between socio-economy and carbon emission by applying EKC hypothesis (Al-Rawashdeh et al., 2015; Alvarez-Herranz and Balsalobre-Lorente, 2015; Zhang et al., 2017). Others, however, did not find a strong inverted U-shape relationship in using the hypothesis, arguing that the theory is not universally applicable to different research contexts, such as low-income countries (Al-Mulali et al., 2015; Liddle, 2015; Dogan and Turkekul, 2016). Other limitations of the EKC hypothesis have also been appreciated. Yang et al. (2015) pointed out that research results by using EKC hypothesis would be affected by the econometric models adopted. For example, the nexuses between economic growth and carbon emission can be "N" shape, monotonous rise or monotonous decline relations when the econometric models are linear, Logarithmic linear, logarithmic squared, or logarithmic cubic polynomials models (Wang and Wei, 2014). Another limitation of applying this hypothesis is the optimistic premise that low-carbon economy can be achieved in future (Liobikienė and Butkus, 2017), which in fact cannot be guaranteed as future is full of uncertainties. For example, as developed countries have been moving highly polluting enterprises to developing countries, it is possible that some developing regions, whose economic progress depends on these high carbon emission industries, cannot achieve the low carbon economy (Gill et al., 2017). This limitation also lies in decoupling theory, which has a similar premise with the EKC hypothesis. The decoupling theory is formed on the basis that the nexus between socio-economic development and carbon emission will decrease or no longer exist, in other words, that low-carbon economy can be achieved (Chen et al., 2017).

Moreover, there are other models available for investigating the relationship between socio-economic growth and carbon emission by identifying key socio-economy factors which affect carbon emission. For example, IPAT model is a typical method for analyzing the environmental impact (I) through investigating the factors of population (P), affluence (A) and technology (T) (Roca, 2002). Nevertheless, the application of IPAT model is based on the assumption that the three factors *P*, *A* and *T* are equally important, which is not always the case. To address this limitation, STIRPAT (stochastic impacts by regression on population, affluence and technology) model was introduced (Wang et al., 2017a). The STIRPAT model allows the three factors *P*, *A* and *T* to be further decomposed and to be assigned with different weighting values. However, the STIRPAT model would become more complex when the three factors are further decomposed.

The other two typical decomposition approaches for exploring the driving factors of carbon emission include index composition analysis (IDA) and structural decomposition analysis (SDA) model, but both also have limitations in application. IDA model has historically allowed only a few factors (GDP per capita, energy intensity, energy consumption, and industrial structure) to be considered, and the application of SDA method largely depends on Input–Output tables, which cannot be obtained in many cases (Xie et al., 2017).

Furthermore, there are other econometric models to explore the nexus between carbon emission and socio-economy by using empirical data, such as cointegration tests, causality tests and data envelopment analysis (DEA). Cointegration is to describe the relationship between two or more than two time series variables. However, the application of cointegration usually requires a large span of data, which will not be available in many applications (Liobikienė and Butkus, 2017). Additionally, cointegration test cannot tell the causality between socio-economy and carbon emission though it can present whether there is cointegration relationship between the two variables. Causality tests are therefore introduced. A widely-referred causality test model is Granger Causality Test model. However, it is criticized that this model cannot be used as a criterion to judge the true causality rather a prediction (Granger, 2001). In this context, Data Envelopment Analysis (DEA) model is considered as a more suitable method than Cointegration Tests and Causality Tests for analyzing the relation between socio-economy and carbon emission (Inman et al., 2006). Mardani et al. (2016) also opined that DEA model is an effective model to evaluate the energy efficiency and carbon emission efficiency. However, as commented by Sueyoshi et al. (2016), DEA model is based on the assumption that the improvement of the production technology always promotes efficiency, which is not necessarily true in many cases.

The above discussions demonstrate the importance of identifying a more effective approach to enhance the understanding on the relationship between socio-economy and carbon emission. As socio-economy and environment are two systems, this paper investigates a system approach as an assessment tool, namely, an improved coupling coordination degree model for analyzing the relationship between socio-economy and carbon emission.

Coupling theory is a principle to describe the relationship between two or more systems that have impact on each other through internal mechanism (Zhou and Lin, 2017). It has been applied in various disciplines, such as chemistry (Li et al., 2011), engineering (Yu, 1989) and biology (Komili and Silver, 2008). In recent years, coupling coordination degree model has been used for conducting research in the environmental field. For example, Zhao et al. (2016) adopted a dynamic coupling coordination degree model to evaluate the coordination between urbanization and eco-environment in the Yangtze River Delta. By applying coupling coordination degree model, Li et al. (2012) discovered a U-shaped curve of the coordination between urbanization and environment by referring to the case of Lianyungang city. In applying coupling principle, Wang et al. (2014) illustrated a S-shaped curve of the coordination between urbanization and the environment in the context of Beijing-Tianjin–Hebei. It can be seen that the coupling theory is a proven effective approach in examining relationship between two or more systems that have interaction with each other. This coupling based model is therefore adopted in this study to assess the coordination level between socio-economy and carbon emission systems.

Coupling coordination degree model includes two coefficients, namely the contribution coefficients of two concerned systems respectively to the degree of coordination level between the two systems (Li et al., 2012; Wang et al., 2014). However, the two coefficients were defined subjectively. In lots of literature, the two contribution coefficients have been subjectively assigned with the value of 0.5 (Geng et al., 2011; Zhang et al., 2016; Wang et al., 2017b). Nevertheless, a few research works have noted the impact of the subjectivity on the coordination degree (Li et al., 2012; He et al., 2017). Therefore, this subjectivity is considered to have the possibility of distorting assessment results. The distorted results would not provide proper insight to