Habitat International 46 (2015) 196–205

Contents lists available at ScienceDirect

Habitat International

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

An improved spatial error model for the mass appraisal of commercial real estate based on spatial analysis: Shenzhen as a case study

Ran Zhang [a], Qingyun Du [a, c, *], Jijin Geng [b], Biao Liu [b, d], Yikun Huang [b, e]

[a] School of Resource and Environmental Science, Wuhan University, Wuhan, 430079, China
[b] Center for Assessment and Development of Real Estate, Shenzhen, 518000, China
[c] Key Laboratory of Geographic Information System, Ministry of Education, Wuhan University, Wuhan, 430079, China
[d] Geoinformation Science, Chinese University of Hong Kong, China
[e] Real Estate and Construction, University of Hong Kong, China

ARTICLE INFO

Article history:
Available online 31 December 2014

Keywords:
Mass appraisal
Spatial analysis
Spatial error model
Fuzzy mathematics

ABSTRACT

Due to the rapid urbanization in China, the government must explore a new sustainable source of fiscal revenue. Therefore, property tax reform has been the topic of active discussion. As an important technical support for property tax reform, mass appraisal is an effective technique for implementing the tax base assessment. To achieve high precision and reduce the cost of valuation, an innovative framework for commercial real estate appraisal is proposed through the introduction of a spatial error model (SEM), fuzzy mathematics and econometrics. Several modifications are made to the conventional SEM so that it can be extended to the solution of commercial property mass appraisals. The fuzzy mathematics approach is adopted to specify the spatial weight matrix (SWM). Additionally, based on econometrics, the impacts of the entity and locatio0n factors on commercial real estate prices are discussed. The proposed method is then implemented for commercial real estate, based on the empirical analysis of Shenzhen. Experiments demonstrate the accuracy of the assessment results and that the consistency among different appraisal objects is improved. Further, through the introduction of fuzzy mathematics, we extend the SWM construction from a single variable to multi-variables. This advantage allows us to increase the usage of our technique and to provide technical support for the undergoing property tax reform in the Chinese real estate market.

Introduction

The real estate sector plays a pivotal role in China's national economic development. The governments' fiscal revenues rely on the land market (Nitikin, Shen, & Zou, 2012). However, due to the revenue reduction of land grants, property tax reform is becoming increasingly important for both central and local governments.

As the basis for property tax, tax base assessment is very important. Mass appraisal (MA) is an internationally-adopted method for property tax assessment and urban planning (Joseph, Robert, & Richard, 2002). The International Association of Assessing Officers (IAAO) published the "Standards on MA of Real Property" and defined MA as follows (Committee, 2011): mass appraisal is a process of evaluating a group of properties as of a given date using common data, standard methods, and statistical testing. Additionally, the results of mass appraisals can assist city planners in implementing urban planning (Ahn, Byun, Oh, & Kim, 2012).

The traditional method for the implementation of the mass appraisal is the hedonic model. In recent years, the Computer-Assisted Mass Appraisal (CAMA) was introduced to the mass appraisal industry; the more complicated algorithm can be used to improve the mass appraisal model (Kontrimos & Verikas, 2011). For example, Peterson and Flanagan (2009) introduced the neural network hedonic pricing model for mass appraisal. Kontrimos and Verikas (2011) implemented the mass appraisal of real estate based on computational intelligence. Additionally, Evgeny and Elena (2012) used a random forest algorithm for residential real estate valuation and a CART-based approach for model diagnostics. Through the application of these new algorithms, the accuracy and fairness of assessment results are improved significantly.

* Corresponding author. School of Resource and Environmental Science, Wuhan University, Wuhan, 430079, China.
E-mail addresses: zhangran_789@163.com (R. Zhang), qydu@whu.edu.cn (Q. Du), gengjj@gmail.com (J. Geng), liubiao0726@gmail.com (B. Liu), huangyikun@21cn.com (Y. Huang).

http://dx.doi.org/10.1016/j.habitatint.2014.12.001
0197-3975/

However, the existing studies of mass appraisals are mostly concentrated in the area of residential real estate. Furthermore, commercial properties play an important role in urban planning (Lau & Li, 2006). Moreover, commercial properties have unique characteristics, which vary from those of residential properties (Fisher, Geltner, & Webb, 1994). One of the most important characteristics of commercial properties is spatial autocorrelation (Kato, 2012). The characteristics of commercial properties are geographically distributed and, hence, should be calculated in the model to explain the prices of commercial properties (Hajime, Yoshiki, & Morito, 2013). Based on the characteristics of commercial properties, we apply a modified spatial model for the mass appraisal of commercial properties.

Section (Literature review and background) reviews past literature on the China's fiscal reform and presents an overview of the tax base assessment in Shenzhen. Section (Methodology) provides a detailed description of the SEM-MA. Section (Study area and data preparation) applies the SEM-MA algorithm to the empirical analysis of Shenzhen, China. A detailed discussion of the results is provided in Section (Results and discussion). Section (Conclusion) presents the conclusions from our findings, as well as a brief discussion of the implications of our research.

Literature review and background

The government revenue from land grants is gradually reduced. In China, land is owned by the state in cities and by collective authorities in rural areas. For urban areas, land can be mobilized for construction. In rural areas, it is usually requisitioned from the collectives (Cho & Choi, 2014). Granting applies only to state-owned land, i.e., land in the cities. Today, granting is the most common mode of land distribution, representing about 70% of all land distributed (Cho & Choi, 2014). Additionally, granting is the most important sources of fiscal revenue for local governments (Tang, Wong, & Liu, 2011). However, the land that can be granted is limited. Property tax reform has increasingly become a focus of attention in China as a means to expand local government fiscal revenue (Hou, Ren, & Zhang, 2013).

The main driving force of this work includes the following aspects. First, fiscal decentralization from the central to local government encourages local governments to expand their revenue. Thus, it can help ensure the fiscal independence of local governments (Tang et al., 2011). Second, a property tax can provide a stable source of fiscal revenue for local governments (Wu, Gyourko, & Deng, 2010). Third, a property tax can be treated as a potential macroeconomic management tool to regulate property market development (Wang, Shao, Murie, & Cheng, 2012). Because house prices in China increased at an average annual nominal rate of 11% in the two decades preceding 2009 (Li & Chand, 2013), the central government implemented a strict policy to control the real estate market. Fourth, a property tax could narrow the gap between the rich and the poor and contribute to stabilizing the ever-increasing urban house prices (Hou et al., 2013).

Within this context, the Shenzhen municipal government effectively performs and implements the relevant requirements of the country's taxation departments. On July 11, 2011, the tax system platform of transaction prices was officially launched in Shenzhen. It is designed so that transaction prices shall not be lower than the government's guidance price. Therefore, it strengthens the management of real estate transactions to achieve the goal of inhibiting the excessive growth of housing prices. In this way, the Shenzhen municipal government accumulated certain experience for the future property tax reform.

Methodology

The modified spatial model, i.e., the spatial error model (SEM), has encountered significant success in many fields, especially in real estate market analysis. Although the SEM has achieved significant success (Anselin, Lozano-Gracia, Deichmann, & Lall, 2010), the practical difficulties in its application include the confirmation of the spatial weight matrix (SWM) (Hajime et al., 2013). Two basic types of SWMs are used in weight construction. The first type of SWM, called the contiguity-based SWM, is established on shared borders, which are characterized by vertices of lattice or irregular polygon data (Anselin, 2002). The second type establishes a relationship based on the distance between observations (Bell & Bockstael, 2000). Additionally, based on these two classical types, several other new methods have been introduced to the SWM construction. Bell and Bockstael (2000) proposed a generalized-banded approach to the development of a flexible SWM. Huang, Wu, and Barry (2010) introduced an extended GWR model, known as a geographically and temporally weighted regression (GTWR), to address simultaneously both spatial and temporal nonstationarity in real estate market data. Neumayer and Plümper (2012) developed the row-standardization of the SWM to a maximum likelihood.

Overall, the recent studies of SWM construction have mainly been focused on a single variable (distance). However, these methods present several limitations. First, the spatial correlation of commercial real estate has more complicated characteristics: one variable (distance) cannot fully reflect the differences among different properties. Second, when more than one property exists in the same building, the distances between the different properties become very small. Therefore, in such a case, traditional methods cannot be used to build a SWM.

To solve these problems, we introduce the degree of membership and the fuzzy mathematics approach to calculate the SWM. The fuzzy mathematics method, which is based on the "maximum membership degree evaluation," is a comprehensive valuation method and quantitative analysis technique (Tian, Yan, & Li, 2012). Compared with other methods that specify the SWM, the fuzzy mathematics method can select and calculate the attributes of different commercial properties in SWM. Further, the proposed method can solve the problem of target properties existing within the same building. In recent years, the Geographic Information System (GIS) has been widely used in real estate price analysis (Cavailhes et al., 2009; Paterson & Boyle, 2002) and regional analysis (Jacek, 2006; Store & Kangas, 2001). In this paper, we use GIS to select the commercial real estate attributes and then to implement those attributes into the regional analysis. After, the SEM is implemented to commercial real estate.

The SEM-MA model

Linear regression is the most popular technique for building mass appraisal valuation models (Kontrimos & Verikas, 2011). The standard regression model is given by

$$Y = X\beta + \varepsilon \tag{1}$$

where Y is an $n \times 1$ vector of the dependent variable with n observations; X is an $n \times m$ matrix of independent variables; β is an $m \times 1$ vector of coefficients; and ε is an $n \times 1$ vector of errors with the standard deviation σ.

Due to the characteristics of the geographical distribution of commercial real estate, the spatial error model in mass appraisal (SEM-MA), which is a linear regression model with a spatial