Land Use Policy 75 (2018) 21–32

Contents lists available at ScienceDirect

Land Use Policy

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

Automating the land valuation process carried out in land consolidation schemes

Demetris Demetriou[a,b,*]

[a] Land Consolidation Department, 131 Prodromou Street, 1419 Nicosia, Cyprus
[b] School of Geography, University of Leeds, Leeds LS2 9JT, UK

ARTICLE INFO

Keywords:
Land consolidation
Mass land valuation
Automated valuation models
GIS
Hedonic regression modeling

ABSTRACT

Land consolidation is an effectual land management procedure aiming to sustainable development. A critical issue in land consolidation schemes is land valuation which is a type of mass appraisal that is generally carried out using an empirical process. As a result, the process is time consuming, costly and the outcomes are not adequately accurate, reliable and consistent. A solution to these problems is the employment of automated valuation models (AVMs). In this context, this paper presents the development, implementation and evaluation of two hedonic price models based on a linear and a non-linear function combined with a geographical information system (GIS), applied to a case study area in Cyprus. Models tested for quality assurance based on international standards. The evaluation based on international standards showed that the both models produced very good results and a small sample of land values provided by the Land Valuation Committee (LVC) is adequate to automate the land valuation process resulting in an adequate accuracy, reliability and consistency. Consequently, the AVM is highly efficient compared to conventional land valuation methods since it may considerably reduce the time and resources used and provide transparency because the process has been converted from empirical to systematic, analytical and standardized.

1. Introduction

Land consolidation (FAO, 2003; Demetriou et al., 2012) is a powerful land management planning instrument that contributes to rural sustainable development. It is widely applied in Europe and in many countries around the world. It consists of two main components: land reallocation, which involves land tenure reorganization in terms of space and property possession to reduce land fragmentation; and the rural planning that, encompasses the provision of relevant infrastructure, e.g. roads and irrigation networks. Land reallocation which is the most complex part of land consolidation is carried out based on land values of parcels since each landowner, after consolidation, should be granted a property of an aggregate value that should be approximately the same as the original value. As a result, the accuracy assigned to the land values and the reliability of the process have a great impact on the land reallocation and hence its success, fairness and acceptance by the landowners.

Land valuation in land consolidation areas is an empirical mass appraisal process of assigning values to all parcels of the consolidated area and to all of their contents which is carried out by an ad hoc Committee. Values can be monetary, i.e. the market value based on several associated factors; agronomic, which reflects soil quality and land productivity; or a relative dimensionless score. In the case of Cyprus, legislation requires that a market value is assigned separately to each parcel and its contents, i.e. a farmstead or trees. As demonstrated by [names deleted for the review process], land valuation in consolidated areas faces some problems. In particular in Cyprus, land valuation is not based on recognized standards, it is time consuming and hence costly and the outcomes present inconsistencies namely, a strong regional variation has been observed in the coefficients of the land valuation factors. Therefore, the process is not standardized, fully transparent and is sometimes unfair (Sipan et al., 2012), causing bias in the land reallocation. For this reason it produces objections by landowners who usually compare the land value assigned to their land parcels with other similar or neighborhood parcels. Consequently, [names deleted for the review process] has proposed a framework involving a new land valuation process in land consolidation areas having, at its core, mass appraisal (e.g. IAAO, 2013a) using automated valuation models (AVMs) (e.g. IAAO, 2003), which aims to overcome these problems.

Mass appraisal is the process of estimating a market value for a group of properties that belong to the same type by employing

* Corresponding author at: Land Consolidation Department, 131 Prodromou Street, 1419 Nicosia, Cyprus.
E-mail addresses: demdeme@cytanet.com.cy, D.Demetriou@leeds.ac.uk.

https://doi.org/10.1016/j.landusepol.2018.02.049
Received 13 April 2017; Received in revised form 24 February 2018; Accepted 24 February 2018
0264-8377/

automated valuation models (AVM), i.e. computer-based modules mostly based on multiple regression analysis (MRA) (e.g. Milla et al., 2005; Kilpatrick 2011; Schulz et al., 2013) and sometimes may be grounded on a spatial component, i.e. GIS (e.g. Longley et al., 1994; Wyatt, 1996, 1997; Hamilton and Morgan, 2010) or on artificial intelligence (AI) techniques (e.g. Kontrimas and Verikas, 2011; Ahn et al., 2012). The quality of mass appraisal outputs can be evaluated by international standards defined by the International Association of Assessing Officers (IAAO, 2003).

While there is a rich literature on the aforementioned aspects it is focused on residential properties. Similarly, while recently have been arisen several research manuscripts deals with land valuation of agricultural land (e.g. Martinelli, 2014; Choumert and Phelinas, 2015; Hilal et al., 2016) i.e. the type of land included in land consolidation areas, they do not confront and meet the distinctiveness of requirements of land valuation process in land consolidation areas. In particular, the aim of land valuation is not to identify how much is worth to sell (or tax) the land but the reallocation of land i.e. land exchange between landowners (including the state) so accuracy is very important to assure fairness. Moreover, landowners are represented in the land valuation body which carries out valuation hence this type of participation is reflected in the model by feeding it a sample of those land values assigned by the committee. Furthermore, landowners may appeal at two levels against the assigned land values thus transparency is reflected in the model through an analytical and systematic process which is checked via international standards. In addition, the factors define land values may vary from country to country, region to region and case study to case study. Despite the mentioned interesting individualities, the research focusing on land valuation in land consolidation areas is very scarce (e.g.Yomralioglu et al., 2007, for urban land consolidation; and that of Demetriou, (2016a, 2016b) who suggested a new land valuation framework for land consolidationand applied an artificial neural network model to the same case study area, respectively.

In the light of the above, this research aims to implement and test the efficiency of the new proposed land valuation framework for land consolidation schemes (Demetriou, 2016a). More specifically, this research presents and discusses the development, implementation and evaluation of two different AVMs for a case study land consolidation area in Cyprus, by utilizing a linear and a non-linear MRA. The basic research questions are as follows: (i) How efficient and appropriate is the proposed new land valuation framework to replace the conventional process? (ii) What are the most important factors for predicting land market values in land consolidation areas (iii) What is an appropriate sample size to produce acceptable outcomes? Clearly, the contribution of this research refers to the land consolidation field. However, a broader impact refers to valuing agricultural land in the context of mass appraisal schemes by employing GIS.

In order to address the above research plan, Section 2 provides an outline regarding the methods utilised, that is, the automated valuation modeling in terms of development and evaluation; and then Section 3 presents the land consolidation case study area, the available data and the land valuation factors that are taken into account. Afterwards, Section 4 that comprises the heart of the paper encompasses the development of AVMs in terms of specification and calibration for the case study area based on two methods, i.e. linear MRA and a non-linear function. Next, Section 5 provides an extensive model evaluation based on testing and quality assurance tests defined by the IAAO and finally, conclusions and recommendations for further research are stated in Section 6.

2. Methods utilized

2.1. The development and evaluation of AVMs

The development process of AVMs based on standards and specifications have been defined by the IAAO (2003) involves three basic steps followed in this research: (i) model specification; (ii) model calibration; and (iii) model testing and quality assurance (IAAO, 2013b).

Model specification involves defining the model type that reflects the valuation method, i.e. cost, sales comparison and income approach, which is in essence transformed into a mathematical formula categorized as additive, multiplicative and hybrid (IAAO, 2003); and the selection of independent variables that will be included in the model as predictors of the market value (dependent variable). Both tasks are very important so as to develop an effective and accurate model. Calibration is the process of testing the model structure to estimate variable coefficients/parameters using a different dataset employed for the last step, i.e. testing the performance of the model by utilizing ratio studies (IAAO, 2013b). This research calibrates models by employing MRA (hedonic regression) including two types of functions, i.e. linear and non-linear based on a GIS. In practice, specification and calibration is a common iterative process until statistical model performance indices are acceptable.

The third step, i.e. model testing and quality assurance, involves testing the model performance with a property sample (called a holdout sample) that has not been used before in model calibration. Ratio studies are recognized as powerful tools for evaluating the performance of AVMs hence IAAO (2013b) introduced standards which are adopted in this research and include four basic measures: (i) appraisal level (mean, median, weighted mean) representing accuracy (ii) variability-uniformity (coefficient of dispersion-COD), reflecting consistency (iii) reliability (confidence interval) and (iv) vertical inequities (price-related differential-PRD, price related bias-PRB) also reflecting accuracy and consistency. Detailed description of these metrics are provided in IAAO (2013b) manual. In addition to the above metrics, the root mean squared error (RMSE) and the mean absolute percentage error (MAPE) have also been used. Furthermore, in order to measure how the error deviates, the absolute percentage error is estimated, which is referred to as the forecasting error (FE) by Nguyen and Cripps (2001) reflecting the proportion of predictions which have a difference compared with the true values by a certain percentage.

2.2. Hedonic regression modeling

Hedonic regression modeling is the oldest statistical calibration methodology, which has been utilized for estimating property values and has gained the most attention compared to other methods since the 60 s and early 70 s (Smith, 1971) until present day (Milla et al., 2005; Schulz et al., 2013). It is based on multiple regression analysis (MRA), which is one of the most well-known statistical methods with a huge range of applications, in particular for prediction and forecasting. It involves estimating the relationship between a dependent variable (Y), one or more independent variables (X), the unknown parameters (β) that represent a scalar or a vector and $\mathscr{E}$ representing random errors. Especially, the general regression model $Y \approx f(X, \beta) + \mathcal{E}$ can be either linear or non-linear. While a linear equation has one basic form, nonlinear equations can take many different forms, e.g. exponential, polynomial, asymptotic, spline, etc. Nonlinear regression uses a computationally intensive, iterative approach that can only be explained using calculus and matrix algebra. The method requires initial estimated values for each parameter. In essence, linear regression is just a special case of a non-linear function.

Whilst MRA is a well-defined and widely accepted process included within statistical software packages and involves a series of easily interpreted goodness-of-fit statistics, it presents some deficiencies (IAAO, 2003). In particular, it ignores spatial autocorrelation (as shown by Demetriou, 2016a) and spatial heterogeneity (Jahanshiri et al., 2011) hence a specific investigation needs to be carried out within a GIS. As shown by Helbich et al. (2014) heterogeneity should always be taken into account because it leads to a lower model fit and worse accuracies. In addition, MRA requires an adequate sample size that may be large and it cannot adequately represent non-linear relationships even with