MODELLING OF COMMERCIAL PROPERTY MARKET SEGMENTATION TO IMPROVE PRICE PREDICTION ACCURACY IN MALAYSIA

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PTTA UTHM
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DEDICATION

I dedicated this thesis to my dear my parents, my wife, my children and my family - the family of Alhaji Usman Dungu Aliyu.

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ABSTRACT

The commercial property market is strategic to the global economy. Significant attention is therefore given to its pricing by various stakeholders. The most common price modelling technique is the traditional hedonic price model. The commercial property market is too complex to be modelled by the traditional single equilibrium model. Property market segmentation models are used to improve the accuracy of price modelling, mostly reported in the housing market. This research, therefore, aims to propose a commercial property market segmentation model to improve price prediction accuracy in Malaysia. 14,043 commercial property transaction records obtained from Malaysia's National Property Information Centre (NAPIC) was used. The submarkets were delineated using conventional hedonic, data-driven and spatial econometrics approaches. The evidence of submarket existence was determined using the Chow test and weighted RMSE, MAE and MAPE. The research found a significantly high level of spatial dependence in Malaysia's commercial property market. Submarkets were efficiently delineated using all the methods except using submarket dummies. The research proposed the spatial error model using adaptive kernel maximum KNN spatial weight matrix as the optimal model for commercial property market segmentation in Malaysia. The proposed model improved the model fit by 19.76 per cent, reduced the RMSE, MAE and MAPE by 20.82 per cent, 24.63 per cent, and 25.92 per cent, respectively. The research shows that accounting for spatial dependence in the commercial property market reduces error, improves model fit and increases the accuracy of price modelling. The research has contributed to the existing body of knowledge by extending the commercial property market segmentation from a priori methods to the empirical data-driven and spatial econometrics approach in Malaysia. The implication to policymakers, financial institutions, the economy, property valuers, and property investors is that the findings will guide them in making informed decisions regarding the differentiated commercial property market.

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ABSTRAK

Pasaran harta tanah komersial adalah strategik untuk ekonomi global. Justeru, pemegang tarah telah menumpukan perhatian yang ketara terhadap perubahan harganya. Teknik pemodelan harga yang sering digunakan adalah pemodelan hedonik umum. Pasaran harta tanah komersial adalah kompleks untuk dimodelkan berasaskan suatu model keseimbangan tunggal. Model segmentasi pasaran harta tanah telah digunakan untuk meningkatkan ketepatan pemodelan harga seperti yang sering digunakan didalam kajian berkaitan harta tanah kediaman. Oleh itu, penyelidikan ini bertujuan untuk mencadangkan model segmentasi pasaran harta komersial bagi menambah baik ketepatan ramalan harga di Malaysia. Sebanyak 14,043 transaksi harta tanah komersial telah diperolehi daripada Pusat Maklumat Harta Tanah Malaysia (NAPIC). Ke semua sub pasaran telah dikenal pasti menggunakan kaedah hedonik konvensional, didorong data dan pendekatan ekonometrik spatial. Kewujudan sub pasaran telah dibuktikan dengan menggunakan kaedah *Chow test* serta RSME, MAE dan MAPE. Hasil kajian telah menunjukkan tahap kebergantungan spatial yang tinggi di dalam pasaran harta tanah komersial Malaysia. Setiap sub pasaran telah berjaya dikenal pasti dengan menggunakan semua kaedah kecuali sub pasaran *dummy*. Kajian ini mendapati bahawa model *spatial error* yang menggunakan adaptif kernel maksimum KNN matriks pemberat spatial sebagai model optimum bagi segmentasi pasaran harta komersial di Malaysia. Model yang dicadangkan telah meningkatkan kejituan model sebanyak 19.76 peratus, mengurangkan RMSE, MAE dan MAPE masing-masing sebanyak 20.82 peratus, 24.63 peratus dan 25.92 peratus. Kajian ini menunjukkan bahawa penggunaan kaedah kebergantungan spatial dapat mengurangkan ralat, meningkatkan kejituan model dan menambahbaik ketepatan model harga untuk pasaran harta tanah komersial. Kajian ini telah menyumbang kepada pengetahuan dengan memanjangkan segmentasi pasaran harta komersial daripada kaedah priori kepada pendekatan didorong data dan ekonometrik spatial di Malaysia. Dapatan kajian ini dapat memberi panduan kepada pihak penggubal polisi, institusi kewangan, ekonomi, penilai harta tanah dan pelabur harta tanah dalam membuat keputusan berkaitan pasaran harta tanah komersial.

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LIST OF ABBREVIATIONS

AIC	Akaike Information Criterion
ANFIS	Adaptive Neural Fuzzy Inference System
ANN	Artificial Neural Network
AVMs	Automated Valuation Models
BIC	Schwarz's Bayesian Criterion
BIS	Bank of International Settlement
BSTAR	Bayesian Spatiotemporal Autoregressive
CAR	Conditional Autoregressive
CBD	Central Business District
DBScan	Density-Based Spatial Clustering Association with Noise
DID	Differences-in-Difference
EGLS	Estimated Generalised Least Squares
EM	Expectation-Maximisation
ESDA	Exploratory Spatial Data Analysis
FCM	Fuzzy C-Mean
GDP	Gross Domestic Product
GMM	Clustering using Gaussian Mixture Models
GWR	Geographically Weighted Regression
HPM	Hedonic Price Model
IMF	International Monetary Fund
IRB	Inland Revenue Board
IVSC	International Valuation Standard Council
KDE	Kernel Density Estimation
KMO	Kaiser-Meyer-Olkin
KNN	K-Nearest Neighbours
LISA	Spatial Indicators of Spatial Association
LL	Log-Likelihood
LM	Lagrange Multiplier

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LTV	Loan to Value Ratio
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MLM	Multilevel Modelling
MLP	Multilayer Perceptron
MPC	Mean Price Comparable
MRA	Multiple Regression Analysis
MWTP	Marginal Willingness to Pay
NAPIC	National Property Information Centre
OLS	Ordinary Least Squares
PCA	Principal Component Analysis
PCA	Principal Component Analysis
RBF	Radial Basis Function
RICS	Royal Institution of Chartered Surveyors
RMSE	Root Mean Squared Error
SAR	Simultaneous Autoregressive
SEM	Spatial Error Model
SLM	Spatial Lag Model
SSR	Sum of Squared Residual
STAR	Spatiotemporal Autoregressive
SWM	Spatial Weight Matrix
VAR	Vector Autoregressive
WLS	Weighted Least Squares

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CHAPTER 1

INTRODUCTION

1.1 Study Background

Globally, the property market is strategic to economic development as it affects individuals, institutions and the economy in general. To the individuals, it provides them with the avenue to have their shelter and accommodation, a source of income to those that let their properties, provides employment opportunities to the teaming members of the populace and serves as their dominant asset and liability (Brunes, Hermansson, Song & Wilhelmsson, 2020; Mora-Garcia, Cespedes-Lopez, Perez-sanchez, Marti & Perez-Sanchez, 2019; Owusu-Ansah, Anim-Odame & Azasu, 2020; Seo, 2016; Usman & Lizam, 2016; Wu, Cheng & Young, 2017). Financial institutions rely heavily on the property market for their loan advances. For instance, the financial institutions in Europe lent over €40billion to only one sector of the property market alone in 2015 (Heinig *et al.*, 2016). The market is worth over $200 Trillion because it is a preferred investment destination of investors and accounts for a substantial share of the lending portfolio (Ab. LahSani, 2011; Heinig *et al.*, 2016; KnightFrank, 2019; The Economist, 2019). Thus, the need for examining the dynamism of the market.

The aggregation of spatially dispersed, clustered and concentrated land uses interconnected by public infrastructure and amenities forms the urban areas. This scenario is fuelled by urbanisation and increased rural-urban migration (He *et al.*, 2017). The urbanisation process is required to be planned and managed carefully. The first urbanisation process involves clustering neighbouring properties that are spread across space and time to become a city. With increasing commercial activities, smaller cities gradually expand to become larger cities, subsequently metropolitan before

finally becoming a mega-urban area. While some cities exhibit a monocentric pattern, many urban areas are polycentric, with numerous urban nuclei surrounded by various land uses (Burhan, 2014; Drennan & Kelly, 2011; Dunse, Jones, & White, 2010).

Property market provides employment opportunities, a market for construction raw material, contributes to the gross domestic product (GDP), and serves as the dominant asset and liability of households and businesses and accounts for the largest share of financial institutions lending portfolio. However, most attention is given to the housing market, leaving the commercial property market. The commercial property market is the segment of the property market that deals with properties held for investment purposes such as retail outlets, shops, shopping complexes, malls, hotels, offices, etc. The commercial property market is equally important to economic and financial systems (EuropeanCommission/ECB, 2016; Raposo & Evangelista, 2017; Wiley, 2017). Globally, banks financial institutions have been increasingly dependent on commercial property loans, and commercial property assets are continuously used as collateral for other loans types (Özyurt, 2014). Significant attention is given to property pricing by various stakeholders such as investors, financial institutions, policymakers, and researchers. The stakeholders use the outcome of the property market for taxation, investment, and price index construction purposes which are useful for both fiscal and monetary policies (Fuerst, Liu & Lizieri, 2016; Mayer, Bourassa, Hoesli & Scognamiglio, 2019; Reiss, 2009; Unbehaun & Fuerst, 2018; Wiley, 2017). The major issue of concern is the accuracy of the determined property prices (Feng & Jones, 2016; Fuerst *et al*., 2016; Manganelli, Mare & Nesticò, 2015).

Property prices are traditionally determined using conventional cost, income, and market valuation approaches (Aliyu, Sani, Usman, & Muhammad, 2018). However, increasing transaction volume, the need for recurring property price determination, time and cost-saving necessitated the use of mass appraisal techniques (Abdullahi *et al.*, 2018). The Hedonic Pricing Model (HPM) is used to estimate property prices from a vast sample of comparable properties. The theoretical foundation of HPM has its root in the seminal work of Rosen (1974). Rosen (1974) shows that price of a commodity is the function of the implicit price of its constituent parts. Relying on the monocentric theory, the property is viewed as heterogeneous good whose price is inversely related to the central business district. The hedonic function modelled property price as the summation of the implicit prices of its

structural characteristics, neighbourhood features and location (Abidoye & Chan, 2017a; Baudry & Maslianskaia-pautrel, 2016; Fotheringham & Park, 2018; Mora-Garcia *et al*., 2019).

The hedonic function is developed based on "one-price-for-all" and the assumption of spatial equilibrium of supply and demand for the various property characteristics. The attributes are assumed to have constant implicit prices across space (Costa *et al.*, 2016; Costa & Cazassa, 2018; Geltner & Van de Minne, 2017). However, this basic assumption of equilibrium price for each characteristic and homogeneous market has been criticised, especially when modelling with regional data (Dale-Johnson, 1982). The use of the aggregated hedonic model in estimating property prices has been criticised due to some reported problems such as spatial autocorrelation and heteroskedasticity. The assumption that properties are spatially independent is less likely to be valid in hedonic price function as the residuals of property price in a regression model have been found to show spatial dependence even when location effects are controlled (Bourassa, Cantoni, & Hoesli, 2007; Fotheringham & Park, 2018). Spatial autocorrelation makes price estimation in the hedonic model inefficient and causes problems in price modelling (Manganelli *et al*., 2015; Tu, Sun & Yu, 2007; Wu, Ye, Ren & Du, 2018). These issues in the traditional HPM are required to be treated to improve the accuracy of price prediction.

The property market is heterogeneous, illiquid, rarely traded and has information asymmetry. These imperfect market features are more pronounced in commercial properties, which are more volatile and exhibit multiple market equilibria (Chiang, 2016; Costa *et al.*, 2016; Wiley, 2017). The use of "one-price-for-all" in a heterogeneous market leads to aggregation bias, which affects the estimated coefficients and the model's predictive capacity. These modelling biases are minimised by segmenting the property market into submarkets that are homogenous within and heterogeneous across such that the price per property attribute unit is constant within the submarket (Bourassa *et al*., 2007; Dale-Johnson, 1982; Keskin & Watkins, 2017; Pryce, 2013).

The reason for property market segmentation is to identify property submarkets within which properties are homogeneous, and property prices are spatially dependent. Property market segmentation is the delineation of the property market into submarkets such that the properties are relatively similar and have constant implicit prices. According to Baudry and Maslianskaia-pautrel (2016), "market segmentation

occurs if and only if, at market equilibrium, a partition of the market, with homogenous groups of consumers within each part, emerges. The different elements of the partition are referred to as submarkets". Market segmentation improves price prediction accuracy such that property price information of one property can be used in the valuation of another property within the same submarket even where comparable evidence is not available from the immediate property neighbourhood (Adair *et al*., 1996; Chegut *et al*., 2013; Ke, Sieracki & White, 2017).

The property market is segmented using different methods. The earliest method of delineating property market was based on a priori segmentation where properties are classified into submarkets based on existing predefined boundaries using conventional hedonic pricing (Palm, 1978; Schnare & Struyk, 1976). Later, data was used to empirically derive submarket using different statistical methods such as Principal Component Analysis (PCA), cluster analysis, fuzzy analysis, artificial neural network, and spatial econometrics (Barreca, Curto & Rolando, 2018; Bourassa *et al*., 2007; Bourassa, Hamelink, Hoesli & Macgregor, 1999; Bourassa, Hoesli & Peng, 2003; Burhan, 2014; Kauko, Hooimeijer & Hakfoort, 2002; Keskin & Watkins, 2017; Seo, 2016; Tu, Sun, & Yu, 2007). There appears to be a consensus on the improvement of property price prediction through market segmentation. However, there is a lack of consensus on what constitutes a submarket and how it should be determined (Beracha, Hardin III & Skiba, 2018; Bourassa *et al*., 2007; Calka, 2019; Gabrielli, Giuffrida & Trovato, 2017; Islam & Asami, 2010).

Spatial dependence is mostly eminent within submarkets. Spatial dependence is defined as the spatial influence of the prices of neighbouring properties on a particular property (Copiello, 2020; Das *et al*., 2020; Morales *et al*., 2020). The Tobler (1970) first law of geography states that "everything is related to everything else, but nearer things are more related than distant things". Property values are more likely to be influenced by their neighbouring properties. Unlike the conventional OLS method, the spatial econometric models incorporate the spatial component into the models such that the dependence caused by the properties location relative to the neighbouring properties is accounted for. Several studies show spatial dependence in property market data (Fotheringham & Park, 2018; Ke *et al*., 2017; Nappi-Choulet & Maury, 2009; Tu, Yu & Sun, 2004).

Malaysia, like other emerging economies, has a burgeoning property market. The property market has shown significant growth over time. Ling, Almeida, Shukri

and Sze (2017) reported that property-related investments in Malaysia rose significantly from 18 per cent in 2005 to 25 per cent of the total investment in 2016. They also reported that the property market is linked to more than 120 industries providing jobs to about 1.4 Malaysian and contributing about 10 per cent to the GDP. This shows the strategic importance of the property market to the Malaysian economy. Most of the research efforts in Malaysia focused on the housing segment of the property market, leaving an equally important commercial property sector with limited attention. Malaysia's commercial property market is second to the residential property market in terms of value. It accounts for 16.7 per cent of the total value of transacted properties as of the Q3 of 2018 (NAPIC, 2019b). The market enjoys relative but volatile growth over the years, as presented in figure 1.1 below.

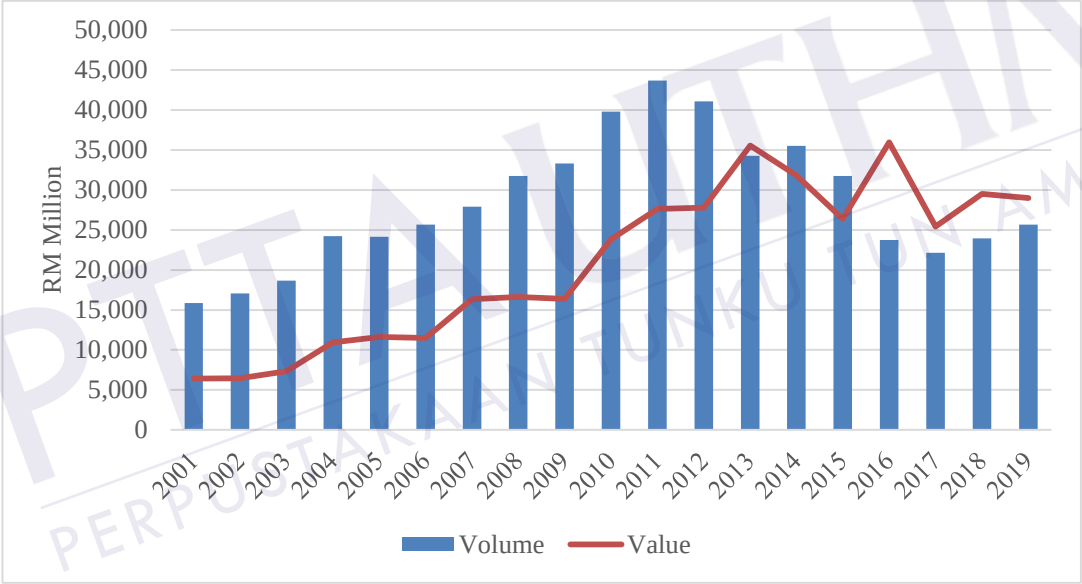

Figure 1.1: Malaysia's commercial property transaction (NAPIC, 2020)

Figure 1.1 showed the volume and value of commercial property transactions from 2001 to 2019. The figure showed an increasing trend from 2001 until 2011—the volume and value of the transactions fluctuate afterwards. The figure also showed an increasing trend from 2018. Despite the declining trend at some points, the commercial property market improves in 2018 relative to the residential property market. The decline is attributed to the imbalance in the demand and supply of commercial properties resulting from increasing commercial property overhang over the years (NAPIC, 2019c). Such a volatile market require much emphasis on the accuracy of its assets' pricing.

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