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DOES ARTIFICIAL INTELLIGENCE ENHANCE HOUSE PRICE FORECASTING ACCURACY? – A LITERATURE REVIEW

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ABSTRACT

The fast-changing housing industry demands the adoption of advanced approaches to valuation for a quick, reliable and accurate result. The traditional approach for forecasting house prices, called the Hedonic Pricing Model (HPM), is problematic given its inaccuracy due to problems with heteroskedasticity and multicollinearity among variables in the model. Recently, there is increasing attention in the application of Artificial Intelligence (AI) to forecast house prices. AI, through Artificial Neural Network (ANN), addresses the shortcomings of HPM. Hence, this paper aims to critically review previous studies on the ability of ANN as a substituted model for HPM in forecasting house prices. Various secondary sources were involved due to extracting various documentary data. It was concluded that the application of AI-enhanced forecasting is accurate. This was demonstrated through the superior predictive performance of ANN compared to HPM.

1.0 INTRODUCTION

Real estate is an industry that plays a significant role in a country's economic development. As evidenced in previous literature, it was found that in 2014, more than half the total value of the world's wealth is from the real estate industry (Rotimi & Albert, 2016). The traits of real estate itself, namely durability, being inflation-proof and stable in income return, amongst others, maximizes wealth and attracts the attention of investors. Thus, an accurate and reliable estimation of real estate price measurement is crucial for the economic and financial decisions of investors.

Developments in real estate requires a proper valuation and market advice services from real estate valuers. There are various approaches for real estate price valuation and forecasting, with Hedonic Price model (HPM) being the most dominant model used. However, the unreliability and inaccuracy of the current valuation method caused a major problem in the real estate industry (Zurada *et al.*, 2006; Rotimi, & Albert, 2016). The fast-changing industry calls for an application of a more sophisticated property appraisal type that is related to Artificial Intelligence (AI) such as the Artificial Neural Network (ANN) model. It has the ability to produce fast, reliable and accurate valuation figures (Yalpir, 2014).

Thus, this paper critically reviews previous studies on the capability of the ANN model to forecast house prices, and it is compared to HPM. Based on archived articles, this study provides a narrative review in the context of house price forecasting methods. Relevant sources of literature for the study was extracted

from various databases, including Scopus, Web of Science and Science Direct.

This paper is organized into five sections, namely introduction, house price forecasting methods, house price forecasting studies, discussion and conclusion.

2.0 HOUSE PRICE FORECASTING METHODS

There is a plethora of methods for forecasting house prices with HPM dominating the literature.

2.1 Hedonic Pricing Model

Hedonic Pricing Model (HPM) is based on the assumption that a commodity such as a house, consists of a bundle of attributes which consumers will purchase to maximize their satisfaction and personal preferences (Limsonbunchai *et al.,* 2004). The property attributes (for example, the number of bedrooms and bathrooms, parking facilities and size of the lot) implicitly influence the market prices.

Although HPM is capable of controlling the characteristics or attributes of properties (Selim, 2009), this method is debated due its instability in producing price coefficients.

In addition, the inability of the HPM to capture nonlinearity effectively and the exposure to multicollinearity and heteroskedasticity problems (Limsonbunchai *et al*., 2004; Kilpatrick, 2011; Antipov & Pokryshevskaya, 2012) beset the predictive performance of HPM, causing inaccurate estimations (Do & Grudnitski 1992; Tay & Ho, 1992; Worzala *et al.*, 1995, among others). The weaknesses of HPM led to more research on alternative methods to HPM.

2.2 ARTIFICIAL NEURAL NETWORK

Artificial Neural Network (ANN) as one of AI approaches mimics the human brain's learning processes (Pagourtzi *et al.,* 2007). It has been identified as capable of addressing the problems of the hedonic model (Tabales *et al.,* 2013). Although ANN is deemed to be a "black-box" (Limsombunchai *et al.*, 2004; Lam *et al.*, 2008) and produce different possibilities of output, its advantages outweigh the disadvantages. An ANN model is able to handle a complex or incomplete dataset (Rummelhart, 1986) that contain outliers (Cechin *et al.*, 2000) and non-linear relationships (Taffese, 2007); it is user-friendly (Mora-Esperanza, 2004) and produces a highly precise output (Borst, 1991; Do & Grudnitski, 1992).

3.0 HOUSE PRICE FORECASTING STUDIES

Recently, there is an increasing interest in the application of ANN in forecasting house prices (Limsombunchai *et al.,* 2004). However, exploration of the ANN application was dominated by researchers in developed economies countries, instead of developing countries such as Malaysia (Selim, 2009; McCluskey *et al.*, 2012; Mooya, 2015; Rotimi & Albert, 2016; among others). Tay and Ho (1992) pioneered the application of ANN in valuation. A total of 1,055 sale prices that covered seven postal districts in Singapore were used to construct and compare the predictive performance of HPM and the Back Propagation Neural Network (BP) model. They concluded that Neural Network is an easy-to-use approach and is an excellent alternative to HPM. Similar comparative studies between HPM and ANN conducted by other researchers also highlighted the superior performance of ANN over HPM. This includes Brazil (Cechin *et al*., 2000), New Zealand (Limsombunchai *et al.,* 2004), Greece (Pagourtzi *et al.,* 2007), Turkey **(**Selim, 2009) and Nigeria (Rotimi & Albert, 2018).

Meanwhile, Lin and Mohan (2011) evaluated the predictive performance of three different models, namely HPM, Additive Nonparametric Regression (ANR) and ANN using 33,342 observations from the United States of America (USA). The prediction accuracy of the three models developed in this research is evaluated by using Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and Theil's U statistics. It was found that when compared to the ANR model, the ANN produced smaller prediction errors due to its ability to handle the nonlinear relationship between the independent variables underlining the ANN's architecture. The results further concluded that ANN is

considerably more accurate, reliable and cost-effective compared to other models.

Amri and Tularam (2012) studied the forecasting performances of house price models using linear and non-linear approaches. House sales price models were developed and compared through Multiple Regression Analysis (MRA), Neural Network (NN) and Adaptive Neuro-Fuzzy (ANFIS). The GIS method was used for data integration in the study area (Bathurst, Australia). Based on the Adjusted R^2 and Mean Squared Error (MSE) value, the analysis revealed that the neural network model outperformed the other non-linear model (i.e. ANFIS) and MRA.

Additionally, Khashei and Bijari (2010) conducted a comparative study on the predictive capabilities between ANN, Auto-Regressive Integrated Moving Average (ARIMA), and Zhang's hybrid. The forecasting performance of proposed models is measured through MAE and MSE. The study concluded ANN to be an effective and flexible approach with a high level of precision and also a good model, especially for time series forecasting.

However, the performance of ANN reduces over a more extended period of time when neural networks alone are applied. Hence, this study suggested that by using a combination of ANN and ARIMA, it is capable of capturing all of the patterns in the data and is an effective way to produce a more accurate result. In addition, when using a hybrid method, the uncertainty of a model that comes from the changing patterns in the data that typically occurred in a time series prediction, can be reduced.

Table 1.0: House price forecasting studies

Author/Year	Data and Country	Pricing Models	Variables	Findings
Tay and Ho (1992)	Singapore	- MRA - Neural Network	- Property attributes - 1,055 sale prices in 1989 - Seven districts in Singapore are covered	ANN is a straightforward approach to use and a reasonable pricing model for mass appraisal of residential prices compared to the traditional MRA model
Cechin *et al*. (2000)	Porto Alegre	- MLP Neural Network	- Property attributes	A neural network is able to do estimation with less error than the linear regression method
Limsombunchai *et al*. (2004)	Christchurch, New Zealand	- HPM - ANN	- Property attributes - Geographical variables	ANN has excellent potential for housing price prediction
Selim (2009)	Turkey	- HPM - ANN	- Property attributes	ANN is a better alternative model for house prices prediction in Turkey
Khashei and Bijari (2010)	-	- ANN - ARIMA - Zhang's hybrid	- MAE and MSE as performance indicators	- ANN is an effective and flexible approach with a high level of precision - A good model for time series forecasting
Lin and Mohan (2011)	USA	- MRA - Additive nonparametric regression	- Property attributes - 33,342 residential houses	- ANN model produced smaller prediction errors - ANN model was found as a more reliable, accurate and cost-effective method for mass appraisal of residential housing
Amri and Tularam (2012)	Bathurst, Australia	- MRA - Neural Network - Adaptive Neuro-Fuzzy (ANFIS)	- Property attributes	- Neural network model outperformed the other models - Showed by Adjusted R^2 values and Mean Squared Errors
Pagourtzi *et al*.	Attica urban	- Multiple Linear	- Environmental	- ANN is an efficacy model and

(2007)	area in Greece	Regression (MLR) - ANN	Geographical variables - Property attributes	able to deal with nonlinear relationships. - ANN performs better than MLR due to nonlinearities issue of the latter forecasting model.
Rotimi and Albert (2018)	Lagos Metropolis, Nigeria	- HPM - ANN	- Property attributes	- ANN outperformed HPM in terms of predictive performance - The finding showed the efficacy and reliability quality of the ANN technique in property valuation

4.0 DISCUSSION

A review of the literature demonstrated the superior capability of artificial intelligence in forecasting a more accurate estimation compared to other models. This is shown through higher values of Adjusted R2 and lower values of MSE, MAE, MAPE and RMSE. However, caution should be exercised when implementing ANN as results may be inconsistent. A neural network, at times, may not outperform HPM even when similar data is used.

5.0 CONCLUSION

This paper critically reviewed the empirical literature on the capability of the substituted model for HPM, which is the ANN in forecasting house prices. The findings of this study highlighted the superior forecasting performance of ANN measured through a range of statistical tests, including Adjusted R2, MAE, MSE, MAPE and RMSE. A higher estimation accuracy achieved through ANN suggests the potential of ANN application in valuing and forecasting real estate prices, especially for house prices. In order to remain relevant in a fast-changing industry, real estate practitioners should apply a more advanced forecasting technique through ANN to obtain a highly accurate prediction result that is beneficial to the decision making of real estate investors and other stakeholders.

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