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THE IMPACT OF NEIGHBORHOOD CHARACTERISTICS ON HOUSING PRICES–AN APPLICATION OF HIERARCHICAL LINEAR MODELING

Lee Chun Chang[1] --- Hui-Yu Lin[2]

[1]*Department of Real Estate Management, National Pingtung Institute of Commerce, Taiwan*

[2]*National Pingtung Institute of Commerce, Department of Real Estate Management, Taiwan*

ABSTRACT

Housing data are of a nested nature as houses are nested in a village, a town, or a county. This study thus applies HLM (hierarchical linear modelling) in an empirical study by adding neighborhood characteristic variables into the model for consideration. Using the housing data of 31 neighborhoods in the Taipei area as analysis samples and three HLM sub-models, this study discusses the impact of neighborhood characteristics on house prices. The empirical results indicate that the impact of various neighborhood characteristics on average housing prices is different and that the impact of house characteristics on house prices is also moderated by neighborhood characteristics.

Key Words: Neighborhood characteristics, House prices, Hierarchical linear modelling (HLM), random effect, Moderate effect.

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INTRODUCTION

Real estate is different from general commodities because of its characteristics, which include its high prices, heterogeneity, immobility, and indivisibility. Following (Rosen, 1974) proposal of the hedonic price model to estimate commodities of multiple characteristics, hedonic price equations have been used by many scholars in the estimation of housing prices. Many studies have used a hedonic price equation to estimate housing prices. Relevant studies confirm that the characteristics of houses, such as their location, age, type, and structure, have a significant impact on house prices (Clapp and Giaccotto, 1998; Martins-Filho and Bin, 2005). In addition to house characteristics, neighborhood characteristics are one of the major factors influencing house prices. When determining the location of their residence, consumers will prioritise the environment and public facilities and services offered by the house's neighborhood. After selecting an appropriate neighborhood environment or the desired public facilities and services, consumers will further consider the house site. This decision-making behaviour implies that the consumer selection behaviour regarding house characteristics is of a hierarchical nature(Quigley, 1985). (Kiel and Zabel, 2008) argue that location is the most important factor affecting house prices, so they developed the concept of 3L (location, location, location) to discuss house prices using the hedonic price model. The research findings confirm that different geographic levels actually have a significant impact on house prices, indicating that residents are concerned about characteristics of

the wider region (quality of the school district or the urban crime rate) in addition to those of the local community (e.g., neighborhood characteristics and street quality).
However, house prices are of the multilevel data type. (Raudenbush and Bryk, 2002) note that previous analyses of multilevel data are vulnerable to problems including aggregation bias, misestimated standard error and heterogeneity of regression because a house itself is not a single object but rather an object belonging to a block, a community, a school zone and a town. Houses in the same neighborhood share the neighborhood's geographic, economic, and social characteristics; that is, they have similar characteristics (Uyar and Brown, 2007). Such neighborhood-level characteristics, such as the socio-natural environment, the living environment, local customs, economic status and the level of medical service will have an impact on samples and enable the residuals to violate the independent assumption of the model, resulting in the overestimation of the error variance and the underestimation of the regression coefficient standard error. Kiel and Zabel (2008) suggest that house prices are determined by characteristics at different levels and that house prices are subject to the impact of factors at different geographic levels. However, the traditional hedonic price model often uses OLS (ordinary least squares) estimation to limit the characteristics data of different levels to a single level, processing data as though they are at one level. However, if the problem of hierarchical estimation is not considered, the hedonic price model is unable to break down the house price variance at different spatial levels and may confuse the house's structural attributes with location characteristics (Jones and Bullen, 1994).

(Hofmann, 1997) suggests that HLM (hierarchical linear modelling) can simultaneously process residuals of different levels and measure the impact of micro-level (or level 1) variables and macro-level (or level 2) variables on outcomes variable and estimate the explanatory variation degree of micro-level outcomes variable. (Brown and Uyar, 2004) use the HLM model to discuss the impact of house characteristics and neighborhood characteristics on house prices, with house characteristics represented by a "living area" as the micro-level explanatory variable and neighborhood characteristics represented by "time to get to the downtown" as the macro-level explanatory variable. The results indicate that, in addition to the direct impact of neighborhood characteristics on house prices, neighborhood characteristics can also moderate the impact of house characteristics on house prices. However, the setting of this model study is relatively simple as neighborhood characteristics have a moderating effect on house characteristics. (Lee, 2009) adds to the macro level (or level 2) two explanatory variables including the convenience of life and sports and leisure to discuss the impact of public facilities on house prices. The empirical results suggest that, at the micro level, the houses' living area has a significant impact on house prices between towns and counties. However at the macro level, the impact of convenience of life varies between counties and towns, whereas the impact of sports and leisure is not significant.(Lee, 2010) discusses the impact of sports and leisure facilities on house prices using micro-level explanatory variables including the living area, the age of the house, the number of rooms, the number of living rooms, the house's structure, the total number of stories in the house and the living floor of the house and macro-level explanatory variable of "sports and leisure facilities". The empirical results suggest that the variable for sports and leisure facilities has a significant impact on house price with cross-level interaction at the same time. In other words, the impact of living area on house prices will be moderated by the impact of sports and leisure facilities.

This study uses the HLM model to further discuss the relationship between house prices and neighborhood characteristics. Neighborhood characteristics contain three variables, which are "environmental quality", "sports and leisure facilities" and "convenience of life". This study intends to elucidate the differences in house prices of neighborhoods in Taipei and to analyse how many differences in house prices are caused by different neighborhood characteristics, whether there is any difference by neighborhood regarding the impact of house characteristics on house prices and whether neighborhood characteristics can moderate the impact of house characteristics on house prices. In other words, this study aims to understand whether the marginal value of the impact of house characteristics on house prices is moderated by neighborhood characteristics.

The remainder of this paper is organised as follows: Section 2 introduces the setting of the empirical model; Section 3 presents data processing and variables; Section 4 discusses the empirical results and analysis; and Section 5 provides the conclusions.

SETTING OF EMPIRICAL MODEL AND VARIABLE EXPLANATION

Setting of Empirical Model

This paper uses three HLM sub-models, which are the null model, the random coefficient regression model, and the slopes-as-outcomes model for empirical studies. The model settings are presented below

Null Model

This method tests whether average house prices in various neighborhoods of Taipei are different without considering any explanatory variables. The main purpose of the model is to distinguish the intra-neighborhood (intra-group) and inter-neighborhood (inter-group) variation in house prices in an analysis similar to the one-way ANOVA. As the inter-group effect (u_{0j}) is a random effect, the model is thus called the "one-way ANOVA with random effect", and the model settings are as follows:

Level 1: $Price_{ij} = \beta_{0j} + r_{ij}, r_{ij} \sim N(0, \sigma^2)$, [1]

Level 2: $\beta_{0j} = \gamma_{00} + u_{0j}, u_{0j} \sim N(0, \tau_{00})$, [2]

where P_{ij} is the price of the i^{th} house in neighborhood j; β_{0j} is the group mean of the housing prices in the j^{th} neighborhood; σ^2 is the variance of the error term, r_{ij} (i.e., variances within groups); γ_{00} is the grand mean housing price for all of the dwellings in the sample; and the error term, u_{0j} represents the random effects associated with neighborhood j and is assumed to have a mean zero and variance of τ_{00}. The null model is derived by adding equation [2] to equation [1] as follows:

mixed model: $Price_{ij} = \gamma_{00} + u_{0j} + r_{ij}$. [3]

This is the standard one-way ANOVA model with mean γ_{00} with a neighborhood effect u_{0j} and a house effect r_{ij}. Therefore, it is possible to treat equation [3] as an ANOVA model when examining whether there are variances in the average housing prices in respective neighborhoods. In other words, it is used to validate "the differences between individual housing prices and the average housing prices of the neighborhoods". If the variance between groups, the random component, yields a significant test result, the average house price differs between neighborhoods. Therefore, it is necessary to consider differences between neighborhoods. If the test result is not significant, it is acceptable to ignore the differences between the neighborhoods. This operation implies that the data can be treated as a single level and can be estimated with equation [1].

However, if there are differences in the average housing prices of respective neighborhoods, it is necessary to use equation [3] so that different regression equations are applied for respective neighborhoods.

In the null model, $Var(P_{ij}) = Var(u_{oj} + r_{ij}) = \tau_{00} + \sigma^2$. If $\rho = \tau_{00} / (\tau_{00} + \sigma^2)$, ρ is called the intra-class correlation coefficient (*ICC*) or cluster effect (Raudenbush and Bryk, 2002). The *ICC* measures the proportion of variance in the dependent variable that is accounted for by the group (i.e., level 2 units). This coefficient shows the proportion of variance in house prices that is attributable to differences at the neighborhood level. For example, this paper uses the intra-class correlation coefficient (*ICC or ρ)* to represent the variance between the factors that influence housing prices in neighborhoods as a percentage of the total variance of housing prices. As soon as the variances of the average housing prices of different neighborhoods are confirmed, further discussion of the variables concerning neighborhoods, which can explain such variances, becomes possible.

Random Coefficient Regression Model

When the null model confirms that the inter-group variation in dependent variables is significant, the explanatory variables of house characteristics are added at the micro level, including area ($Area$), house age (Age), house type ($Type$), house structure ($Struc$), and interior environment ($Nenvi$) by the cantering of the grand mean and setting the intercept and slope as random effects. The purpose of doing so is to test whether the variation of intercepts and slopes between groups is significant. The model settings are as follows:

Level 1:

$$Price_{ij} = \beta_{0j} + \beta_{1j}(Area_{ij} - Area_{..}) + \beta_{2j}(Age_{ij} - Age_{..}) + \beta_{3j}(Type_{ij} - Type_{..}) + \beta_{4j}(Struc_{ij} - Struc_{..}) + \beta_{5j}(Nenvi_{ij} - Nenvi_{..}) + r_{ij}, r_{ij} \sim N(0, \sigma^2) \quad [4]$$

Level 2:

$$\beta_{0j} = \gamma_{00} + u_{0j}, u_{0j} \sim N(0, \tau_{00}) \quad [5]$$

$$\beta_{1j} = \gamma_{10} + u_{1j}, u_{1j} \sim N(0, \tau_{11}) \quad [6]$$

$$\beta_{2j} = \gamma_{20} + u_{2j}, u_{2j} \sim N(0, \tau_{22}) \quad [7]$$

$$\beta_{3j} = \gamma_{30} + u_{3j}, u_{3j} \sim N(0, \tau_{33}) \quad [8]$$

$$\beta_{4j} = \gamma_{40} + u_{4j}, u_{4j} \sim N(0, \tau_{44}) \quad [9]$$

$$\beta_{5j} = \gamma_{50} + u_{5j}, u_{5j} \sim N(0, \tau_{55}). \quad [10]$$

No level 2 explanatory variable (neighborhood characteristics) is added in the random coefficient regression model, and only the impact of level 1 explanatory variables (house characteristics) on dependent variables is taken into consideration. In the proposed model, variables including the living area ($Area$), house age (Age), house type ($Type$), house structure ($Struc$), and interior environment ($Nenvi$) will be added to understand whether level 1 explanatory variables have a significant impact on dependent variables. A significant level of random error variance means the marginal values of level 1 house characteristics are not fixed but random, indicating there are other factors of influence causing the differences in house prices in various neighborhoods.

Slopes-as-Outcomes Model

The slopes-as-outcomes model can evaluate whether level 2 explanatory variables can moderate the impact of level 1 explanatory variable on dependent variables. A moderating effect exists between level 2 variables and level 1 variables, and the explanatory power of a level 1 variable can change in strength with a change in a level 2 variable. The settings are as follows:

Level-1:

$$Price_{ij} = \beta_{0j} + \beta_{1j}Area_{ij} + \beta_{2j}Age_{ij} + \beta_{3j}Type_{ij} + \beta_{4j}Struc_{ij} + \beta_{5j}Nenvi_{ij} + r_{ij}$$

$$r_{ij} \sim N(0,\sigma^2) \quad [12]$$

Level- 2:

$$\beta_{0j} = \gamma_{00} + u_{0j}, u_{0j} \sim N(0,\tau_{00}) \quad [13]$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}ENVI_j + \gamma_{12}CONV_j + \gamma_{13}LESI_j + u_{1j}, u_{1j} \sim N(0,\tau_{11}) \quad [14]$$
$$\beta_{2j} = \gamma_{20} + \gamma_{21}ENVI_j + \gamma_{22}CONV_j + \gamma_{23}LESI_j + u_{2j}, u_{2j} \sim N(0,\tau_{22}) \quad [15]$$
$$\beta_{3j} = \gamma_{30} + \gamma_{31}ENVI_j + \gamma_{32}CONV_j + \gamma_{33}LESI_j + u_{3j}, u_{3j} \sim N(0,\tau_{33}) \quad [16]$$
$$\beta_{4j} = \gamma_{40} + \gamma_{41}ENVI_j + \gamma_{42}CONV_j + \gamma_{43}LESI_j + u_{4j}, u_{4j} \sim N(0,\tau_{44}) \quad [17]$$
$$\beta_{5j} = \gamma_{50} + \gamma_{51}ENVI_j + \gamma_{52}CONV_j + \gamma_{53}LESI_j + u_{5j}, u_{5j} \sim N(0,\tau_{55}) \quad [18]$$

Statistically significant levels of $\gamma_{11} \sim \gamma_{13}$, $\gamma_{21} \sim \gamma_{23}$, $\gamma_{31} \sim \gamma_{33}$, $\gamma_{41} \sim \gamma_{43}$, and $\gamma_{51} \sim \gamma_{53}$ indicate the existence of moderating effects between level 2 variables and level 1 variables; that is, the neighborhood characteristics can moderate the impact of house characteristics on house prices.

Variable Instructions

The level 1 variables of this study concern house characteristics, the level 2 variables of this study concern neighborhood characteristics, and house prices are the dependent variable. The level 1 explanatory variables include living area ($Area_{ij}$), house age (Age_{ij}), house structure ($Struc_{ij}$), house type ($Type_{ij}$) and interior environment ($Nenvi_{ij}$), and the level 2 explanatory variables include the neighborhood environmental quality, convenience of life and sports and leisure facilities. The selected variables are illustrated as follows and are summarised as shown in Table 1.

Examining level 1 variables, Martins-Filho and Bin (2005) confirm that house area has a significant impact on house prices. A larger house area is associated with a higher price. However, this paper expects the impact of house area on house prices to be positive. Martins-Filho and Bin (2005) suggest that house age has a significant impact on house prices. Due to physical depreciation that occurs over time, older houses are associated with lower house prices. Therefore, the impact of the age of the house on house prices is negative. Regarding the house type ($Type_{ij}$), Ma and Lin (2007) conclude from their empirical study that the house type has a significant impact on house prices. Lin and Lin (1993) note that the house types may not be fully consistent with the research expectations due to complexity in the types and uses of buildings in Taiwan. Therefore, this study cannot predict the differences in prices of congregate houses and other types of houses. Regarding the house structure ($Struc_{ij}$), Lin (2004) and (Ma and Lin, 2007) suggest that house structure has a significant impact on house prices and that the prices of houses constructed of steel or steel concrete are higher than those of houses made of brick. Regarding the interior environment ($Nenvi_{ij}$), this paper explores the impact of the interior environment on house prices in the case of individual houses. When the interior environment is better, house prices will be higher; therefore, the interior environment has a positive impact on house prices.

With regard to level 2 variables, the explanatory level 2 variable is represented by the neighborhood characteristics. This paper uses neighborhood environmental quality ($ENVI_j$), convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) as variables affecting house prices. Better neighborhood environmental quality ($ENVI_j$), convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) have a greater impact on house prices. The impact of three variables on house prices is expected to be positive.

Table- 1. Description of Variables at Different Levels in HLM

Variable		Description	Expected signs
Independent variable	$Price_{ij}$	The natural logarithm of house price, which is the real transaction price in unit of ten thousand NT$	
level 1variable	$Area_{ij}$	The natural logarithm of interior use area (including balcony) measured in pings (1 ping equals 35.58 sq. ft.)	+
	Age_{ij}	The natural logarithm of house age starting from completion to year 2006 measured in years	-
	$Type_{ij}$	House type was set as a dummy variable. If it is a congregate house, then $Type_{ij}=1$; otherwise, $Type_{ij}=0$ (for example, traditional farmhouse, independent house, detached house and row-house)	+/-
	$Struc_{ij}$	House structure was set as a dummy variable. If the house is constructed of steel or steel concrete and reinforced concrete, then $Struc_{ij}=1$; otherwise, $Struc_{ij}=0$ (for example, brick structure or reinforced brick structure)	+
	$Nenvi_{ij}$	interior environment	+
level 2 variable	$ENVI_j$	neighborhood environmental quality	+
	$CONV_j$	neighborhood convenience of life	+
	$LESI_j$	neighborhood sports and leisure facilities	+

DATA COLLECTION AND DESCRIPTION OF SAMPLE STATISTICS

This paper sources data on house prices and house characteristics from the "2006 Survey of Residential Status by Agency of Construction and Planning, Ministry of Interior Affairs". With the Taipei region as the analysis subject, the 2,727 batches of data cover houses in 31 neighborhoods. Because the characteristics of real estate differ, thus making the prices vary greatly, the observation values may contain a number of outliers. To avoid the impact of such outliers on the calculation of statistics and inference results, this paper first eliminates neighborhoods with sample data below 5 batches to analyze the remaining 31 neighborhoods; it then eliminates the neighborhood data associated with the highest or lowest 5% of house prices; finally, it uses the Dffits outlier elimination method to delete the outliers in the samples to obtain the final 2,482 batches of data.

In addition, data on house interior environment, environmental quality, convenience of life, and sports and leisure facilities are sourced from the "2006 Survey of Residential Status by the Agency of Construction and Planning, Ministry of Interior Affairs". "House interior environment" includes the following: living area, ventilation conditions, sunshine lighting, housing insulation, privacy, drainage, housing situation, leaking and cracking damage; "environmental quality" includes the following: air pollution, noise, sanitation, garbage disposal and drinking water quality; "convenience of life" includes: external transport, food shopping, medical facilities, elementary and high schools, post office or financial institutions; "sports and leisure facilities" includes the following: parks, sport facilities, libraries or art venues, landscape and community beautification. The satisfaction items are measured using a 5-point Likert scale.

Table 2 lists the descriptive statistics of the mean value, standard deviation and correlation coefficient of various variables. Table 2 illustrates that the average house price is 4.3703 million

NTD (US$1=NT$30, as of November 2011); the average living area ($Area_{ij}$) is 32.45 pings (1 ping equals 35.58 sq. ft.); the average house age (Age_{ij}) is 17.99 years. Regarding the house type, congregate houses account for 70% of the total number of houses, and the remaining types account for 30%; in terms of house structure, houses made of steel, steel concrete or reinforced concrete account for 88% of the total, and houses made of brick or reinforced brick account for 12%.

House prices and house age (Age_{ij}) are negatively correlated, indicating that house prices will decrease with increasing house age (Age_{ij}); house prices and area ($Area_{ij}$), house type ($Type_{ij}$), house structure ($Struc_{ij}$), interior environment ($Nenvi_{ij}$) are all positively correlated, indicating that the prices of congregate houses and steel or steel concrete structure will be higher than other types of houses. House prices will be higher in case of larger living area and better interior environment. Living area ($Area_{ij}$), house age (Age_{ij}), house type ($Type_{ij}$), house structure ($Struc_{ij}$), and interior environment ($Nenvi_{ij}$) are all negatively or positively correlated at a low level. House prices and environmental quality ($ENVI_j$), convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) are all positively correlated, indicating that better environmental quality ($ENVI_j$), convenience of life ($CONV_j$) and sports and leisure facilities ($LESI_j$) will result in higher neighborhood average house price.

Table- 2. Correlation Coefficients and Basic Statistics of Variables

	Mean	S.D.	$Price_{ij}$	$Area_{ij}$	Age_{ij}	$Type_{ij}$	$Struc_{ij}$	$Nenvi_{ij}$	$ENVI_j$	$CONV_j$	$LESI_j$
$Price_{ij}$	437.03	1-92	1.00								
$Area_{ij}$	32.45	1.40	0.28***	1.00							
Age_{ij}	17.99	1.92	-0.17***	-0.05**	1.00						
$Type_{ij}$	0.70	0.46	0.05**	-0.16***	-0.09***	1.00					
$Struc_{ij}$	0.88	0.32	0.17***	-0.00	-0.17***	0.26***	1.00				
$Nenvi_{ij}$	3.79	0.69	0.10***	0.19***	-0.16***	-0.06***	0.01	1.00			
$ENVI_j$	3.68	0.81	0.05**	0.08***	-0.07***	-0.05**	-0.03	0.49***	1.00		
$CONV_j$	4.00	0.83	0.05**	-0.09***	0.10***	0.12***	0.03	0.23***	0.23***	1.00	
$LESI_j$	3.38	0.89	0.12***	.032	-0.04**	0.04**	0.02	0.39***	0.38***	0.36 ***	1.00

Notes: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01

EMPIRICAL RESULTS

Null Model

This paper uses the null model to test the variation in "average house price" between various neighborhoods. As shown in Table 3, in terms of fixed effects, the average γ_{00} estimated value of the average house price of various neighborhoods is 6.0337($e^{6.0337}$ =4.170337 million NTD, US$1=NT$30, as of November 2011). In terms of random effects, the estimated value of τ_{00} is 0.1045, and the statistics of χ^2 is 504.3897, the degree of freedom is 30 (J =31 neighborhoods), reaching a significance level of 1%. This result indicates that the average house price varies significantly in various neighborhoods.

By the variance τ_{00} in the neighborhood average price β_{0j} and the micro-level intra-group variance σ^2, we can calculate the intra-group correlation coefficient ρ or $ICC =$ 0.2272. According to the criteria proposed by Cohen (1988), it is a strong correlation, indicating that 22.72% of the variance in the average house price is caused by neighborhood differences; therefore, general regression models cannot be used for estimation and differences caused by various neighborhood characteristics should be considered. In addition, the reliability of the sample mean λ_j is 0.929, indicating that the reliability is very high when using the estimated value of the average house price of various neighborhoods as the real average price indicator.

Table- 3. Analysis Results of the Null Model

Fixed effects	Coeff.	se	t-ratio	p-value
γ_{00}	6.0337***	0.0592	101.855	0.000
Random effects	Variance components	df	Chi-square	p-value
τ_{00}	0.1045***	30	504.3897	0.000
level 1 σ^2	0.3554			
Deviance (-2LL)	4567.7587			
Number of estimated parameters	2			

Notes: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01

Random Coefficient Regression Model

The primary feature of the random coefficient regression model is its ability to allow the regression lines of various neighborhoods to move freely. In other words, there are no limitations on intercepts and slopes and no limitations on the homogenous conditions of various neighborhoods. The differences in the average house price of various neighborhoods may be caused by quality of neighborhood characteristics and the availability of public facilities. A difference between various neighborhoods indicates that the differences in the average house price of various neighborhoods are not entirely caused by the characteristics of houses and that the neighborhood characteristics are one of the major factors of influence.

As shown in Table 4, the fixed-effect aspect demonstrates that living area ($Area_{ij}$), house age (Age_{ij}), house structure ($Struc_{ij}$) and average house price show significantly strong correlations ($\hat{\gamma}_{10} = 0.5097$, t =10.538; $\hat{\gamma}_{20} = -0.1522$, t =-4.412; $\hat{\gamma}_{40} = 0.1500$, t =3.735). Living area ($Area_{ij}$) and neighborhood average house price are positively correlated, indicating that a larger living area leads to a higher average house price; prices of houses with house structures ($Struc_{ij}$) of steel, steel concrete or reinforced concrete will be higher. House age (Age_{ij}) has a negative impact, indicating that higher house age results in lower average house price. These values imply that the three variables can effectively predict the changes of the average house price in various neighborhoods.

In terms of random effects, the estimated value of τ_{00} is 0.0742, and the χ^2 statistical capacity is 151.425, the degree of freedom is 27, reaching a 1% significance level. This level of significance indicates that there is significant variance between 31 neighborhoods. In terms of estimated values of slopes variance, the relationships of house age (Age_{ij})($\hat{\tau}_{22} = 0.0216$, χ^2 =61.1310, df

=27), house type ($Type_{ij}$)($\hat{\tau}_{33} = 0.0219$, χ^2 = 43.4352, df =27), interior environment ($Nenvi_{ij}$)($\hat{\tau}_{55} = 0.0042$, χ^2 = 41.8889, df =27) and average house price vary greatly in between various neighborhoods, indicating that the impact of house age (Age_{ij}), house type ($Type_{ij}$), interior environment ($Nenvi_{ij}$) on house price will vary due to different neighborhood characteristics in the case of different neighborhoods.

Compared with the τ_{00} of the null model, after adding important explanatory variables at the micro level, τ_{00} decreases by 0.0303. The micro-level explanatory variable can explain 29% of the average house price differences between various neighborhoods ((0.1045-0.0742)/0.1045), implying that house prices are also affected by other important factors. In the follow-up models, this paper adds the characteristic variables of the neighborhood to explore the impact of the neighborhood characteristic variables on house prices.

Table- 4. Analysis Results of the Random Coefficient Regression Model

Fixed effects		Coeff.	se	t-ratio	p-value
γ_{00}		6.0600***	0.0507	119.533	0.000
$Area_{ij}$	γ_{10}	0.5097***	0.0484	10.538	0.000
Age_{ij}	γ_{20}	-0.1522***	0.0345	-4.412	0.000
$Type_{ij}$	γ_{30}	0.0460	0.0402	1.144	0.262
$Struc_{ij}$	γ_{40}	0.1500**	0.0402	3.735	0.001
$Nenvi_{ij}$	γ_{50}	-0.0221	0.0209	-1.058	0.299
Random effects		Variance components	df	Chi-square	p-value
	τ_{00}	0.0742***	27	151.425	0.000
$Area_{ij}$	τ_{11}	0.0352	27	27.4684	0.385
Age_{ij}	τ_{22}	0.0216***	27	61.1310	0.000
$Type_{ij}$	τ_{33}	0.0219**	27	43.4352	0.017
$Struc_{ij}$	τ_{44}	0.0104	27	32.5230	0.176
$Nenvi_{ij}$	τ_{55}	0.0042**	27	41.8889	0.025
level 1 σ^2		0.2953			
Deviance (-2LL)		4209.9198			
Number of estimated parameters		22			

Notes: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01

Slopes-as-Outcomes Model

This paper uses the slopes as the outcomes model to further test whether slope variance at the micro-level can be explained by the characteristic variables of various neighborhoods by testing whether the value of γ is significantly larger than zero. In this way, the model can test the existence of the moderating effect of the neighborhood characteristic variables.

As shown in Table 5, in the fixed effect part, the coefficients of convenience of life ($CONV_j$) and living area ($Area_{ij}$) are significant ($\gamma_{12} = 0.2134$, t =2.107), indicating that convenience of life ($CONV_j$) will moderate the impact of living area on house prices. A higher level of convenience of life ($CONV_j$) can positively moderate the impact of the average house price per unit in the neighborhood. In other words, the impact of living area on house prices will be moderated by convenience of life.

The coefficients of the convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) and house age (Age_{ij}) are significant ($\gamma_{22} = -0.3475$, t =-4.459; $\gamma_{23} = 0.1961$, t =1.714), indicating that the coefficient of the impact of convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) on house age (Age_{ij}) has a significant moderating effect. The increasing convenience of life ($CONV_j$) will speed up the depreciation of average house price due to increasing house age (Age_{ij}). Uyar and Brown (2007) suggest that the depreciation by house age is faster in neighborhoods with a better environment, implying that real estate developers are more willing to build more houses in areas with superior environments and convenience of life. As a result, the depreciation of old houses will increase faster. Second, in the case of better sports and leisure facilities ($LESI_j$), the impact of house age (Age_{ij}) on house prices will be less pronounced. The marginal price of house age will be moderated by the variable of sports and leisure facilities.
The convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) and house type ($Type_{ij}$) coefficients are significant factors ($\gamma_{32} = -0.3475$, t =-4.459; $\gamma_{33} = 0.1960$, t =2.714), indicating that convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) can moderate the house type coefficient ($Type_{ij}$). The variable of convenience of life ($CONV_j$) has a negative moderating effect on house type. Due to the characteristics of densely populated Taipei, most of the houses in the downtown area are congregate houses. When conditions of convenience of life increase, residents are more willing to live out of the downtown area (also related to lower house prices), and selections for different types of houses will also increase accordingly. In addition, better sports and leisure facilities ($LESI_j$) can positively moderate the average house prices in terms of the house type ($Type_{ij}$). When there are better sports and leisure facilities, prices of congregate house type will increase more apparently than other types of houses.
The variables of environmental quality ($ENVI_j$) and house structure ($Struc_{ij}$) coefficients are at statistically significant levels ($\gamma_{41} = 0.3546$, t =2.208), indicating that environmental quality ($ENVI_j$) has a significant moderating effect on house structure ($Struc_{ij}$). Better environmental quality ($ENVI_j$) can positively moderate the effect of average prices of houses of different structures. Most houses close to the downtown area are of steel concrete or reinforced concrete buildings. In the case of better neighborhood environmental quality in the downtown area, residents are more willing to live in the downtown area, and prices will be higher than other types of houses.

The coefficients of the variables representing sports and leisure facilities ($LESI_j$) and interior environment ($Nenvi_{ij}$) are at the level of significance ($\gamma_{53} = 0.2603$, t =2.083), suggesting that the sports and leisure facilities has a significant moderating effect on the coefficient for interior environment ($Nenvi_{ij}$). Better sports and leisure facilities ($LESI_j$) can positively moderate the impact of houses' interior environment on house prices, indicating that the impact of an interior environment on house prices is moderated by sports and leisure facilities.

In terms of random effects, τ_{00}, τ_{22}, τ_{33}, τ_{55} are all at a statistically significant level, indicating that house prices vary significantly from neighborhood to neighborhood even after macro-level variables, including the environmental quality ($ENVI_j$), convenience of life ($CONV_j$), sports and leisure facilities ($LESI_j$) variables, are controlled for. Meanwhile, micro-level variables, such as house age (Age_{ij}), interior environment ($Nenvi_{ij}$), and house type ($Type_{ij}$), are significantly different between neighborhoods in terms of their impact on house prices, that suggesting some important macro explanatory variables have not been considered.

Finally, this paper summarises the random parameter estimation and model fitness of the random coefficient regression model and slopes-as-outcomes model as shown in Table 6. As shown in Table 6, "average house price", "house age (Age_{ij})", "house type ($Type_{ij}$)", and "interior environment ($Nenvi_{ij}$)" slopes are all at the 10% significance level, indicating that the impact of house characteristics on house prices in various neighborhoods are different in addition to the significant differences in house prices among various neighborhoods in Taipei. This indicates that previous estimations using the hedonic price model to consider neighborhood intercepts and slopes as homogenous can easily lead to bias. In addition, in terms of model fitness, Singer and Willett (2003) use AIC and BIC to compare the model fitness with smaller value representing better fitness. As shown in Table 6, after the addition of the macro-level characteristic variables, the slopes-as-outcomes model has better fitness than the random coefficient regression model.

Table- 5. Analysis Results of the Slopes-as-outcomes Model

Fixed effects			Coeff.	se	t-ratio	p-vale
		γ_{00}	6.0908***	0.0461	132.138	0.000
$Area_{ij}$	Intercept	γ_{10}	0.5682	0.3691	1.539	0.135
	$ENVI_j$	γ_{11}	0.0580	0.1639	0.347	0.731
	$CONV_j$	γ_{12}	0.2134**	0.1013	2.107	0.044
	$LESI_j$	γ_{13}	0.0114	0.1861	0.061	0.952
Age_{ij}	Intercept	γ_{20}	-0.1899	0.1850	-1.027	0.314
	$ENVI_j$	γ_{21}	0.0910	0.0833	1.093	0.285
	$CONV_j$	γ_{22}	-0.3475***	0.0779	-4.459	0.000
	$LESI_j$	γ_{23}	0.1961*	0.1144	1.714	0.098
$Type_{ij}$	Intercept	γ_{30}	-1.0144	1.0229	-0.992	0.331
	$ENVI_j$	γ_{31}	0.0910	0.8325	1.093	0.285
	$CONV_j$	γ_{32}	-0.3475***	0.0779	-4.459	0.000
	$LESI_j$	γ_{33}	0.1960*	0.1144	2.714	0.098
$Struc_{ij}$	Intercept	γ_{40}	0.0332	0.5896	0.056	0.956
	$ENVI_j$	γ_{41}	0.3546**	0.1606	2.208	0.036
	$CONV_j$	γ_{42}	0.1133	0.1864	0.608	0.548
	$LESI_j$	γ_{43}	-0.2411	0.2529	-0.953	0.349
$Nenvi_{ij}$	Intercept	γ_{50}	-0.3640	0.3387	-1.075	0.292
	$ENVI_j$	γ_{51}	-0.1518	0.1074	-1.413	0.169
	$CONV_j$	γ_{52}	-0.0074	0.0714	0.103	0.919
	$LESI_j$	γ_{53}	0.2603**	0.1250	2.083	0.047
Random effects			Variance components	df	Chi-square	p-value
		τ_{00}	0.0682***	26	144.0691	0.000

$Area_{ij}$	τ_{11}	0.0156	23	26.7427	0.267
Age_{ij}	τ_{22}	0.0128*	23	32.4382	0.091
$Type_{ij}$	τ_{33}	0.1308**	23	39.5671	0.017
$Struc_{ij}$	τ_{44}	0.0069	23	28.7290	0.189
$Nenvi_{ij}$	τ_{55}	0.0068**	23	38.2918	0.024
level 1	σ^2	0.2975			
Deviance(-2LL)		4206.7868			
Number of estimated parameters		22			

Notes: * indicates p<0.1, ** indicates p<0.05, *** indicates p<0.01

Table -6. Model Fitness of Random Coefficient Model and Slopes-as-outcomes Model

Random effects		(1) Random Coefficient Model				(2) Slopes-as-outcomes Model			
		Variance components	df	Chi-square	p-value	Variance components	df	Chi-square	p-value
	τ_{00}	0.0742***	27	151.425	0.000	0.0682***	26	144.0691	0.000
$Area_{ij}$	τ_{11}	0.0352	27	27.4684	0.385	0.0156	23	26.7427	0.267
Age_{ij}	τ_{22}	0.0216***	27	61.1310	0.000	0.0128*	23	32.4382	0.091
$Type_{ij}$	τ_{33}	0.0219**	27	43.4352	0.017	0.1308**	23	39.5671	0.017
$Struc_{ij}$	τ_{44}	0.0104	27	32.5230	0.176	0.0069	23	28.7290	0.189
$Nenvi_{ij}$	τ_{55}	0.0042**	27	41.8889	0.025	0.0068**	23	38.2918	0.024
level 1	σ^2	0.2953				0.2975			
Model Fit		-2LL	Parameters	AIC	BIC	-2LL	Parameters	AIC	BIC
		4209.9198	22	4253.92	4381.89	4206.7868	22	4250.79	4378.76

CONCLUSION

This paper uses a multi-level view to discuss changes in house prices. The empirical results suggest that average house prices in various neighborhoods have significant differences and that the impact of house characteristics on average house price differs between neighborhoods. The impact of house characteristics on house prices is moderated by neighborhood characteristics.

First, at the micro level, variables including living area ($Area_{ij}$), house age (Age_{ij}) and house structure ($Struc_{ij}$) have the most significant impact on average house prices. House age (Age_{ij}), interior environment ($Nenvi_{ij}$) and house type ($Type_{ij}$) have different level of impact in various neighborhoods. Second, at the macro level, variables including environmental quality ($ENVI_j$) and sports and leisure facilities ($LESI_j$) have the most significant impact on house prices. Finally, regarding the moderating effect of neighborhood characteristics on house characteristics, convenience of life ($CONV_j$) has a positive (negative) moderating effect on living area ($Area_{ij}$), house age (Age_{ij}), and house type ($Type_{ij}$). Sports and leisure facilities ($LESI_j$) have a positive moderating effect on house age (Age_{ij}), house type ($Type_{ij}$), and interior environment ($Nenvi_{ij}$), respectively. Environmental quality ($ENVI_j$) has a positive moderating effect on the coefficient of house structure ($Struc_{ij}$).

Due to heterogeneity and other characteristics of houses, the neighborhood characteristics of each building may different. The multi-level analysis method can integrate factors of neighborhood characteristics into the model for consideration without studying house prices at a single level, making the research findings closer to reality. In addition, some macro variables affecting house prices have not been considered; therefore, future studies can use neighborhood characteristics variables such as the number of parks in the neighborhood or population density.

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REFERENCES

Brown, K.H. and B. Uyar, 2004. A hierarchical linear model approach for assessing the effects of house and neighborhood characteristics on housing prices. Journal of Real Estate Practice and Education, 7(1): 15-24.

Clapp, J.M. and C. Giaccotto, 1998. Residential hedonic models: A rational expectations approach to age effects. Journal of Urban Economics 44(3): 415-437.

Cohen, J., 1988. Statistical power analysis for the behavioral sciences. Lawrence Erlbaum Associates.

Hofmann, D.A., 1997. An overview of the logic and rationale of hierarchical linear models. Journal of Management 23(6): 723-744.

Jones, K. and N. Bullen, 1994. Contextual models of urban house prices: A comparison of fixed- and random-coefficient models developed by expansion. Economic Geography 70(3): 252-272.

Kiel, K.A. and J.E. Zabel, 2008. Location, location, location: The 3l approach to house price determination. Journal of Housing Economics 17(2): 175-190.

Lee, C.C., 2009. Hierarchical linear modeling to explore the influence of satisfaction with public facilities on housing prices. International Real Estate Review 12(3): 252–272.

Lee, C.C., 2010. The impact of facilities of leisure and sports on housing prices in taiwan: An application of hierarchical linear modeling. Journal of Real Estate Practice and Education 13(2): 159-175.

Lin, C.C. and S.J. Lin, 1993. An analysis of the effect of environment quality and public facilities on housing prices and rents in taiwan. Journal of Housing Studies 1: 21-45.

Lin, S.J., 2004. The marginal willingness-to-pay of star public elementary and junior high school districts in taipei city. Journal of Housing Studies 13(15-34).

Ma, Y.C. and C.C. Lin, 2007. An application of mass appraisal and the hedonic equation in the real estate market in taiwan. Journal of Housing Studies 16(2): 1-22.

Martins-Filho, C. and O. Bin, 2005. Estimation of hedonic prices functions via additive nonparametric regression. Empirical Economics 30(1): 93-114.

Quigley, J.M., 1985. Consumer choice of dwelling, neighborhood and public services. Regional Science and Urban Economics 15(1): 41-63.

Raudenbush, S.W. and A.S. Bryk, 2002. Hierarchical linear models: Applications and data analysis methods. Newbury Park: Sage Publications.

Rosen, S., 1974. Hedonic prices and implicit markets: Product differentiation in pure competition. Journal of Political Economy 82(1): 34-55.

Uyar, B. and K.H. Brown, 2007. Neighborhood affluence, school-achievement scores and housing prices: Cross-classified hierarchies and hlm. Journal of Housing Research 16(2): 97-116.