

# The Effect of the Principal Component Index for Housing Quality Satisfaction on Housing Price: Urban vs. Rural Analysis

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## Abstract

The 2015 Questionnaire Survey on Housing Conditions by the Construction and Planning Agency surveyed four categories of satisfactions on housing quality: living convenience, surrounding environmental quality, satisfaction on interior environment, and satisfaction on exterior environment. This study pioneeringly investigates the effect of housing satisfaction on Taiwanese housing price for six municipalities and other rural area. Since the above four survey categories of housing quality are highly overlapping, to avoid variable interaction, we construct an index for housing quality satisfaction using principle component analysis to reduce dimensionality. After controlling the moderation effect of market condition, the results show that residential area, house age, floor location, and number of floors all significantly affect housing price. More importantly, the index for housing quality satisfaction is positively related to housing price, indicating that better housing quality helps in raising housing price. However, the positive relation does not exist in Taipei City or Kaohsiung City. Consistent with previous studies, stress on high housing price may weaken the need for quality consideration, especially the case of Taipei City. Finally, market variation does not lead to difference in the relation between housing quality satisfaction and housing price.

**Keywords:** housing price, survey of housing conditions, housing satisfaction, principal component analysis, urban

## 1. Research Background and Motivation

Numerous studies have explored the factors affecting housing prices, which included the height of apartment buildings (Kurvinen & Vihola, 2016), spatial house features (Keskin, 2008; Rong & Sun, 2014; Li et al., 2015; Wang & Chen, 2018; Aliyev et al., 2019), housing commercialization and urbanization (Wu et al., 2018; Yuan et al., 2018), quality of the surrounding environment (Bono et al., 2018; Br  ard et al., 2018; Osman, 2018; Li et al., 2019; Peng et al., 2009), transportation accessibility (Agostini, 2008; Huang et al., 2017), housing affordability (Seo et al., 2018), whether a house consignment sale contract has been signed (Aliyev et al., 2019), unique apartment factors (Seo et al., 2018), household income and number of household members (Osman, 2018), real estate market environment, homebuyer identity, homebuyer psychology behavior and homebuying preferences (Chen et al., 2012), and timing and location conditions (Hsu et al., 2011).

This study analyzes the data from the 2015 Report on the Housing Status Survey conducted by the Construction and Planning Agency, Ministry of the Interior, focusing on the effect of living environment quality on housing prices. Novemsky and Schweitzer (2004) empirically state that living environmental quality is positively correlated with value and satisfaction. The aforementioned studies show that among all the variables that affect housing prices, living environment quality is the most critical factor after housing conditions (e.g., house area, floor, and age).

The 2015 Report on the Housing Status Survey reveals that satisfaction with the living environment can be divided into four types, namely satisfaction with the convenience in daily life, surrounding outdoor environment, indoor living environment, and outdoor living environment. Convenience in daily life is related to factors such as the presence of supermarkets, medical institutions, and elementary and junior high schools, whereas surrounding

outdoor environment includes parks, green space, fitness venues, libraries or art and cultural galleries, landscaping management and maintenance, and scenic views. Due to high collinearity among the four types of questionnaire items, homogeneity and anchoring effects across different items can easily lead to biased answers (Black, 1986; Tversky & Kahneman, 1974; Chang et al., 2018). For example, research participants who are satisfied with “convenience in daily life” or “surrounding outdoor environment” tend to answer “satisfied” for the items of “satisfaction with outdoor living environment.” Therefore, this study reduces the dimensionality of some variables and uses principal component analysis (PCA) to construct a single variable for satisfaction with living quality, so that the collinearity caused by item interactions does not affect the analysis results. In real estate research at home and abroad, this is the first attempt aiming to effectively solve the problem of variable selection in regression models and to further improve the consistency of the interpretation of verification results.

After the establishment of the six special municipalities in Taiwan (hereinafter referred to as six municipalities), urban governance has become a new trend in public governance in Taiwan (Wang & Lin, 2016). Under the premise that the administrative resources of special municipalities are more abundant than those of counties and cities, real estate policies and measures in special municipalities carry deeper meanings. Due to limited government financial resources, problems such as unbalanced urban–rural development and the development gap between northern and southern Taiwan still exist. Metropolitan areas are obviously different from other areas in terms of government resource allocation, proportion of young and middle-aged populations, and education levels. In addition to economic factors, the migration pattern of Taiwan’s population and the quality of residential and living environments are key factors affecting housing prices. Huaping and Suodi (2013) claim that the maturity and convenience of culture, transportation, and communication facilities are the primary factors contributing to price differences in commercial residential buildings between cities. Long et al. (2009) and Kolowe (2014) note that compared with nonmetropolitan areas, the residents of metropolitan areas are willing to pay higher housing prices to obtain or use facilities that can improve their living quality. The aforementioned studies indicate that differences in development level may affect urban residents’ requirements and expectations of living quality and may further affect housing prices. Therefore, this study also analyzes the effect of satisfaction with living quality on housing prices for the six municipalities and other nonmunicipal areas in Taiwan.

This study analyzes the effect of satisfaction with living quality on housing prices, and crucial control variables such as housing conditions (e.g., house area, house age, and total number of floors) and economic cycle of the real estate market are included in the analysis. Regarding the factors that affect housing prices, empirical results reveal that the larger the house area and the higher the total number of floors, the higher the housing price. By contrast, the higher the house age, the lower the housing prices; however, the effect of increasing house age on housing prices is less marked. The aforementioned results are generally supported by related literature. Regarding regional price differences among the special municipalities, Taipei City has the highest housing prices, followed by New Taipei City, Taichung City, Kaohsiung City, and Taoyuan City, and Tainan City has the lowest housing prices. The satisfaction with living quality variable constructed in this study has a significant and positive effect on housing prices, indicating that Taiwanese residents are willing to pay higher housing prices for higher living quality. This phenomenon is more obvious in special municipalities such as New Taipei City, Taoyuan City, Taichung City, and Tainan City, as well as in nonmunicipal areas. Surprisingly, no positive relationship is identified between satisfaction with living quality and housing prices in Taipei City and Kaohsiung City. Whether the reason for this result is that residents have difficulty considering living quality under the pressure of high housing prices remains to be further explored in the future.

In general, this study makes the following contributions to real estate research and practice: (1) this is the first study to construct a single variable for satisfaction with living quality by using PCA to explore its effect on housing prices, effectively solving the possible biases and interpretation problems caused by variable selection in regression models; (2) subsample analysis of the data of municipalities and nonmunicipal areas reveal the differences in the urban development level and the importance of living environmental quality; and (3) the analysis results can help real estate companies understand the public’s perception of how living quality affects housing prices and can provide references for establishing policies related to public facilities.

## 2. Literature Review

Various related studies have discussed the factors that affect housing prices, and they have generally focused on spatial housing features, convenience in daily life, and satisfaction with the living environment. The following sections provide brief descriptions of these relevant factors:

### 2.1 Housing Characteristics

Structural features of the house have an obvious and positive effect on housing prices (Rosen, 1974; Lin & Lin,

2014), such as floor area (Guttery, 2002; Sirmans et al., 2005; Wang & Chen, 2018) and total number of floors (Colwell et al., 1998; Dermisi & McDonald, 2010), but building area squared has a negative relationship with housing prices (Fisher et al., 2006). Wang and Chen (2018) apply data mining to determine housing prices, and find that the factors affecting housing prices include the area of the house, house age, number of floors, and number of rooms (Aliyev et al., 2019; Keskin, 2008; Chang et al., 2018).

Floor location is a major price determinant of apartments and high-rise buildings (Singell & Lillydahl, 1990; Aliyev et al., 2019). Floor locations can affect ventilation and lighting. For example, prices for the ground floor are higher due to its commercial value and the right to use the front and rear courtyards, whereas the top floor has a landscape advantage and the availability and use of the top balcony (Chang et al., 2018). The fourth floor is often rejected by homebuyers because the number “4” is pronounced similar to “death” in Chinese; it therefore has lower housing prices (Chang et al., 2016). Kurvinen and Vihola (2016) also discover that the number of floors has a positive effect on apartment prices within a 300-m radius.

Increasing house age and the structural deterioration of buildings can affect building service life, maintenance costs, and housing prices (Chang et al., 2018; Springer, 1996; Guttery, 2002; Sirmans et al., 2005), and the difference is the greatest among different housing prices (Hsu et al., 2015). Using house age squared to capture changes in housing price patterns (Malpezzi et al., 1987; Goodman & Thibodeau, 1995; Goodman & Thibodeau, 1997; Smith, 2004; Wilhelmsson, 2008), researchers suggest that the expected housing price incrementally declines with increasing house age (Chang et al., 2018). In summary, the factors affecting housing prices are generally housing characteristics such as the total number of floors, house area, house age, and house age squared.

### *2.2 Convenience in Daily Life in the Surrounding Environment*

Factors affecting housing prices include variables related to the surrounding environment (Rosen, 1974); residential area location; transport; property charges; transaction volumes; educational facilities; bus lines, mass rapid transits, or high-speed rails (Huang et al., 2017; Agostini, 2008; Tan et al., 2019); renovation and floor areas (Rong & Sun, 2014); convenience in daily life and commercial activities (Osman, 2018; Br  card et al., 2018; Liu et al., 2020); proximity to open spaces (McConnell & Walls, 2005); the commercial districts nearby (Sirmans et al., 2005); urbanization (Wu et al., 2018); presence of quality schools (Haurin & Brasington, 1996; Osman, 2018); distance to parks, government service centers, and shopping centers (Zhang et al., 2018); medical facilities (Rika & Hironori, 2020; Osman, 2018); and proximity to scenic spots (Zhang & Wang, 2017). The factors related to life satisfaction that affect housing prices generally include accessibility to parks (Bono et al., 2018), fitness venues, libraries, or art and cultural galleries (Osman, 2018). In addition, views and landscapes affect housing prices.

### *2.3 Other Factors Affecting Housing Prices*

Other factors affecting housing prices include fluctuation trends of the real estate market (Wu et al., 2017; Hui, 2013; Bates & Santerre, 2016; Miao et al., 2020; Annette et al., 2018), noise, air quality, homebuyer identity and their psychological behavior and homebuying preferences, length of residence, average household income, neighbor satisfaction (Zangerle, 1927), earthquake-related risks in the area, access to administrative and parking areas (Wang & Chen, 2018), housing location, maintenance level, number of sales (Aliyev et al., 2019), and access to public services (Li et al., 2019). In addition to housing characteristics and convenience in daily life, other factors of influence are the real estate cycle (Wu et al., 2017; Hong et al., 2015; Hui, 2013; Bates & Santerre, 2016; Miao et al., 2020; Annette et al., 2018), noise conditions (Br  card et al., 2018), real estate market environment, homebuyer identity and their psychological behavior and homebuying preferences (Chen et al., 2012), urban infrastructure (Liu et al., 2020), housing affordability (Seo et al., 2018), socioeconomic characteristics, neighborhood quality, and location factors (Keskin, 2008).

### *2.4 Analysis of Municipalities and Nonmunicipal Areas*

Expansion of the number of cities may lead to a disparity in the development of public facilities between municipalities and nonmunicipal areas (Chou, 2004). In the rapid urbanization process, the planning of the community space is neglected, and the shortage of public facilities, dilapidation, and lack of management lead to the loss of neighborhood characteristics and the disintegration of the community (Lai, 1998). Therefore, urban–rural environmental gaps will affect differences in social needs (Liu, 2008). Urban and rural environments influence regional development (Kuo et al., 2010). The residential area is more crucial than the place of work when establishing social relations in an urban environment (Hsia, 2007). Given the regional development problem in the process of modernization, identifying ways to manage and construct regions to generate an improved quality of life warrants further studies (Kuo et al., 2010). The environment is a possible factor

affecting people's values, and the influence of urban and rural differences should be considered (Yeh, 2012). The concept of environmental protection differs between residents in municipalities and those in nonmunicipal areas (Arcury & Christianson, 1990). Tremblay and Dunlap (1978) claim that the global information network can gradually decrease the gap of transportation and mass communication between urban and rural areas, thus decreasing the difference in people's values.

Urban governance is a new trend in Taiwan. The special municipalities receive abundant administrative resources. Under limited government financial resources, problems such as unbalanced growth between urban and rural areas or the development gap between northern and southern Taiwan still exist. The allocation of government resources in municipal areas is different from that in other areas (Wang & Lin, 2016). The maturity and the convenience of culture, transportation, and communication facilities are the core factors that contribute to price differences in commercial residential buildings between cities (Huaping & Suodi, 2013). Compared with nonmunicipal areas, the residents of special municipalities are more willing to pay higher housing prices to obtain or use facilities that can enhance their living quality (Long et al., 2009; Kolowe, 2014). Relevant studies have also discussed environmental quality in terms of urban and rural differences. For example, Liu et al. (2019) study the effect of urban and rural inequality on the significance and practice of sustainable development in China; sustainable development advocates improved environmental quality and promotes social and environmental justice in the future, and a core goal of sustainable development is transforming the Chinese society from a society divided between urban and rural areas into a green, civilized, and prosperous society. Van de Poel et al. (2009) examine urban–rural disparities through demographic and health surveys and discuss the effect of adverse environmental conditions. Zhang et al. (2017) study urban development and sewage treatment under China's rapid transition from a rural to urban country. In summary, when discussing housing environment and prices, the socioeconomic environment across Taiwan is nonhomogeneous; thus, urban–rural differences should be considered in real estate research (Yeh, 2012).

### 3. Research Methods

This study analyzes the data from the 2015 Report on the Housing Status Survey conducted by the Construction and Planning Agency, Ministry of the Interior to clarify the actual housing demand. The statistical analysis methods used are descriptive statistics, PCA, and multiple regression analysis.

#### 3.1 Description of Data, Sampling, and Variable Setting

##### 3.1.1 Data Description

Data used in this study are from the 2015 Housing Status Survey commissioned by the Construction and Planning Agency; this survey is conducted every 10 years in Taiwan. The valid samples from April 1 to July 15, 2016, are 17 705 homes. The survey includes two items for “living environment conditions” and eight items for “convenience in daily life and satisfaction with the surrounding environment,” which are analyzed and discussed. The details of each item are shown in Table 1. The survey participants are from the six municipalities and other counties and cities, as well as Penghu County, Kinmen County, and Lienchiang County (Matsu Islands), with a total of 22 counties and cities. This study analyzes the influencing factors of housing prices in the six municipalities in Taiwan, and missing and incorrect observations are excluded from analysis. A total of 8560 records are used in the analysis.

In this study, housing price is defined as the price at which the house is built or purchased by the participants during the purchasing year. Consumer price index (CPI) is used to adjust housing prices (Lee et al., 2012) to solve the issue that the real values of currencies vary between different years, that is, the effects of market inflation. In CPI, 2016 is used as the base year, and the annual housing price is adjusted according to the base year.

Table 1. The items of 2015 Housing Status Survey commissioned by the Construction and Planning Agency

Index	Questionnaire number	items	options
convenience in daily life and satisfaction with the surrounding environment	convenience in daily life	20 Supermarket	(1) very convenient (2) convenient (3) normal (4) inconvenient (5) very inconvenient
		21 Medical institution	
		22 Elementary and junior high schools	
	satisfaction	23 Parks and green space	
		24 Fitness venues	(1) None (2.1) Very satisfied (2.2)
		25 Library or arts and cultural gallery	Satisfied (2.3) Fair (2.4) Dissatisfied
		26 Landscaping, management, and maintenance	(2.5) Very dissatisfied
satisfied with the whole living environment	28	27 Scenic views	
		Overall, are you satisfied with the indoor living environment?	(1) Very satisfied (2) Satisfied (3) Fair (4) Dissatisfied (5) Very dissatisfied
	29	Overall, are you satisfied with the outdoor living environment?	(1) Very satisfied (2) Satisfied (3) Fair (4) Dissatisfied (5) Very dissatisfied

### 3.1.2 Variable Setting and Description

In this study, a regression model is employed to analyze housing prices (*PRICE*, unit: NT\$10 000). Because price fluctuation can cause the same amount of currency to have different values in different years, the price is adjusted using CPI following the method of Lee (2012). In addition, heterogenous variation occurs in housing prices (Hendry, 1984; Meen, 1990); therefore, housing prices are transformed to a normal distribution with natural logarithms. The explanatory variables include the house area (*AREA*), house age (*AGE*), and house age squared (*AGE*<sup>2</sup>), which capture variations in real estate price patterns (Malpezzi et al., 1987; Goodman & Thibodeau, 1995; Goodman & Thibodeau, 1997; Smith, 2004; Wilhelmsson, 2008).

Regarding the total number of floors (*BTYPE*), buildings with five floors (inclusive) or less are low-rise apartments; buildings with 10 floors or less are mid-rise apartments; and buildings with 11 floors (inclusive) or more are high-rise apartments. Therefore, regarding the total number of floors, in this study, buildings are divided into buildings with five floors or less (Lee et al., 2012), six to ten floors, and more than 11 floors, and the *BTYPE* values are set to 0, 1, and 2 respectively. Favorable scenic views and the higher cost of higher-floor buildings are expected to have positive effect on housing prices (Lee et al., 2012). The living environment variables include the four variables of *INSIDE*, *OUTSIDE*, *CONV*, and *SATI*. Items in the questionnaire, which are ordinal variables, are measured using a 5-point Likert scale. This study analyzes housing prices in Taiwan's counties and cities; because the Taiwanese population is mostly concentrated in the six municipalities, other counties and cities that do not belong to the six municipalities are classified into one category. The six municipalities as well as other counties and cities are represented by *CITY* and given codes 1 to 7. Taipei City is set as 1 as the benchmark for comparison, and the codes of the other counties and cities (i.e., New Taipei City, Taoyuan City, Taichung City, and Tainan City, Kaohsiung City, and other counties and cities) are set as *CITY2*–*CITY7*, respectively. Because Taipei City is the capital and the most prosperous city in Taiwan, housing prices are expected to be higher than those in other municipalities, and the expected influencing coefficient is negative.

Economic adjustment is conducted based on historical economic peak data published by the Center for Real Estate Research, National Chengchi University. As revealed by the 2015 questionnaire survey, there were four peaks, namely those in 1981, 1989, 1994, and 2007. Therefore, the economic expansion period in this study is the four periods of 1980–1982, 1988–1990, 1993–1995, and 2006–2008. The economic cycle variable (*CYCLE*) is also a categorical variable. The year that falls within the economic expansion period is set to 1, and the year that does not belong to the above four periods is set to 0, indicating an economic contraction period. Generally, a booming economy will have higher housing prices; thus, the direction of influence of the economy on housing prices is expected to be positive. Finally, the other variables that are adjusted using *CYCLE* include the area of the house (*CYC:AREA*), house age (*CYC:AGE*), house age squared (*CYC:AGE*<sup>2</sup>), and residential area [*K(CYC:CITYK)*], which is set as the interaction term, where *K* is the residential area code of *CITY2*–*CITY7*, which can be queried in Table 2.

Table 2. Define variables and description

Variables	Sign of variables	description	Expected direction of influencing coefficient
<b>Dependent Variables</b>			
Housing prices	<i>PRICE</i>	Housing prices (calculated in NT\$10 000 and adjusted using CPI)	---
<b>Explanatory variables (the main effect is as follows)</b>			
House area	<i>AREA</i>	House area (in ping)	+
House age	<i>AGE</i>	Number of years between house construction and questionnaire administration	—
House age squared	<i>AGE</i> <sup>2</sup>	House age squared	+
The total number of floors	<i>BTYPE</i>	The total number of floors in the participants' residence is divided into three types: floors 1–5, floors 6–10, and floors 11 or above, and the coding values are 0, 1, and 2, respectively.	+
Residential area	<i>CITY</i>	The six municipalities that the participants live in are coded as 1 for Taipei City, 2 for New Taipei City, 3 for Taoyuan City, 4 for Taichung City, 5 for Tainan City, 6 for Kaohsiung City, and 7 for other counties and cities.	—
The economic cycle variable <sup>2</sup>	<i>CYCLE</i>	The economic cycle variable is set to 1 in the period of economic expansion (based on peaks in 1980–1982, 1988–1990, 1993–1995, and 2006–2008 according to the data released by the Center for Real Estate Research), and 0 for other periods of economic contraction.	
The indoor living environment	<i>INSIDE</i>	For individual items, the participant's satisfaction with the indoor living environment is rated on a 5-point Likert scale.	+
The outdoor living environment	<i>OUTSIDE</i>	For individual items, the participant's satisfaction with the outdoor living environment is rated on a 5-point Likert scale.	+
Living convenience level	<i>CONV</i>	Values of the three items, such as the items related to supermarkets, medical institutions, and elementary and junior high schools, are averaged.	+
Living satisfaction level	<i>SATI</i>	Values of the five items, such as the items related to parks, green space, fitness venues, libraries or art and cultural galleries, landscaping, and scenic views, are averaged.	
Living quality	<i>QUAL</i>	The four satisfaction variables for measuring quality of life, namely satisfaction with the indoor living environment, satisfaction with the outdoor living environment, convenience in daily life, and life satisfaction, extracted as covariances through PCA are reflect quality of life.	+
<b>Explanatory variables (the interaction effect is as follows)</b>			
economic cycle × house area	<i>CYC:AREA</i>	The effect of economic cycle adjustment (house area) on housing prices	
economic cycle × house age	<i>CYC:AGE</i>	The effect of economic cycle adjustment (house age) on housing prices	
economic cycle × house age squared	<i>CYC:AGE</i> <sup>2</sup>	The effect of economic cycle adjustment (House age squared) on housing prices	
economic cycle × residential area 2 (New Taipei City)	<i>CYC:CITY2</i>	The effect of economic cycle adjustment (residential area: New Taipei City) on housing prices	
economic cycle × residential area 3 (Taoyuan City)	<i>CYC:CITY3</i>	The effect of economic cycle adjustment (residential area)3 on housing prices	
economic cycle × residential area 4 (Taichung City)	<i>CYC:CITY4</i>	The effect of economic cycle adjustment (residential area)4 on housing prices	
economic cycle × residential area 5 (Tainan City)	<i>CYC:CITY5</i>	The effect of economic cycle adjustment (residential area)5 on housing prices	
economic cycle × residential area 6 (Kaohsiung City)	<i>CYC:CITY6</i>	The effect of economic cycle adjustment (residential area)6 on housing prices	
economic cycle × residential area 7 (Other counties and cities)	<i>CYC:CITY7</i>	The effect of economic cycle adjustment (residential area)7 on housing prices	
economic cycle × living quality	<i>CYC:QUAL</i>	The effect of economic cycle adjustment (living quality) on housing prices	

Note 1. Based on Taipei City.

Note 2. According to the data published by the Center for Real Estate Research, the peaks occurred in 1981, 1989, 1991, and 2007.

### 3.2 PCA of Living Environment Quality and Satisfaction Variables

Measurement of convenience in daily life, satisfaction level, and overall satisfaction with the living environment is conducted using a questionnaire designed by the government. A total of 10 items are used to understand the satisfaction level of residents, and these items are then summarized into four major variables. This study uses common representative variables to describe the living quality of residents; hence, PCA is used to extract the main factors from a substantial amount of data and to set them as variables, and these variables are then used to establish a linear prediction model (Stock & Watson, 1998); thus, the variance obtained by the linear combination is the largest, which provides the largest individual differences in these components (Yeh et al., 2010). The original variables are preprocessed using PCA so that the transformed principal components are independent, thereby improving classification accuracy and avoiding the confounding effects of any correlation between dependent variables on the classification results. The lower the correlation between variables, the higher the classification accuracy will be (Yu & Chen, 2006).

PCA was proposed by Pearson in 1901, and it was extended and developed into a statistical method by Hotelling (Gochet et al., 1997; Johnson & Wichern, 2002). The main purpose is to identify fewer base variables from the original variables in the raw data and then use these principal components to explain the variation between the original variables. Precisely, PCA aims to use fewer principal components to explain the variation of a large number of original variables, reducing the dimensionality of the original variables and avoiding computational complexity (Yu & Chen, 2006). The original variables can also be transformed into independent principal components to avoid the influence of variables on the classification results. PCA has the following characteristics: (1) all principal component variables are linear combinations of the original variables; (2) the first principal component can explain the largest amount of data variation; (3) the second principal component can explain the second largest amount of data variation after the first principal component is removed; and (4) all principal components are independent and uncorrelated (Sharma, 1996).

Table 3 presents the eigenvalues and explained variance ratios of the four major satisfaction variables after performing PCA. Only one principal component has an eigenvalue (2.071) greater than 1; therefore, this principal component is extracted according to the Kaiser criterion. Factor loadings of the principal component and the original satisfaction variables are all in the same direction (Table 4), indicating that the extracted principal component and each variable have the same direction of influence. In addition, Table 4 lists the correlation coefficients between the scores obtained by extracting the principal components and each variable, which range from 0.605 to 0.801. Thus, the extracted principal component can represent the common effect of the various satisfaction variables.

Table 3. The eigenvalues and explained variance ratios

the eigenvalue eigenvalue	explained variance ratio Proportion of var.	Cumulative eigenvalue	Cumulative explained variance ratio Cumulative proportion of var.
2.071	0.518	2.072	0.518
0.898	0.225	2.971	0.743
0.609	0.152	3.580	0.895
0.421	0.105	4	1

Table 4. Lists the correlation coefficients between the scores obtained by extracting the principal components and each variable

Variable of satisfaction	loadings	Correlation coefficients
Satisfaction of the indoor living environment	0.421	0.605
Satisfaction of the outdoor living environment	0.557	0.801
Living convenience level	0.537	0.772
Living satisfaction level	0.474	0.683

### 3.3 Establishment of an Empirical Model

In this study, statistical methods are applied to analyze the possible factors that affect housing prices, and the effect of each factor on the housing price and its rationality are determined. Generally, the housing price presents a right-skewed distribution; that is, more houses in the middle and low-price range are available, whereas the number of houses in the higher price range are few. However, housing prices are transformed into natural logarithms for regression analysis. The transformed housing price data display a normal distribution and have homogeneous variance, which is consistent with the assumption for the model in the regression analysis.



In the regression analysis, two models are applied. Model 1 discusses the main effect of possible factors of influence, and Model 2 additionally includes the interaction between *CYCLE* and other variables. In addition, all the data are analyzed in sequence, and different residential areas are analyzed. The classification of residential areas is shown in Table 2, with the six municipalities and other areas. The error term ( $\varepsilon$ ) for each model is assumed to be the same, the mean is assumed to be 0, and the variance is the normal distribution of constants. The analysis modes are listed in order:

Model 1: Only the factors affecting the main items are included.

$$\ln(PRICE) = \beta_0 + \beta_1 AREA + \beta_2 AGE + \beta_3 AGE^2 + \beta_4 BTYPE1 + \beta_5 BTYPE2 + \beta_6 CITY2 + \beta_7 CITY3 + \beta_8 CITY4 + \beta_9 CITY5 + \beta_{10} CITY6 + \beta_{11} CITY7 + \beta_{12} QUAL + \beta_{13} CYCLE + \varepsilon; \quad \varepsilon \sim N(0, \sigma^2)$$

Model 2: The interaction term between the *CYCLE* variable and other variables is included in addition to the factors of influence

$$\begin{aligned} \ln(PRICE) = & \gamma_0 + \gamma_1 AREA + \gamma_2 AGE + \gamma_3 AGE^2 + \gamma_4 BTYPE1 + \gamma_5 BTYPE2 + \gamma_6 CITY2 + \gamma_7 CITY3 + \gamma_8 CITY4 + \\ & \gamma_9 CITY5 + \gamma_{10} CITY6 + \gamma_{11} CITY7 + \gamma_{12} QUAL + \gamma_{13} CYCLE + \gamma_{14} CYC:AREA + \gamma_{15} CYC:AGE + \gamma_{16} CYC:AGE^2 + \\ & \gamma_{17} CYC:CITY2 + \gamma_{18} CYC:CITY3 + \gamma_{19} CYC:CITY4 + \gamma_{20} CYC:CITY5 + \gamma_{21} CYC:CITY6 + \gamma_{22} CYC:CITY7 + \\ & \gamma_{23} CYC:QUAL + \varepsilon; \quad \varepsilon \sim N(0, \sigma^2) \end{aligned}$$

Note. When analyzing the data of different residential areas, the model excludes the *CITYX* variable and its interaction term.

## 4. Empirical Results

### 4.1 Descriptive Statistics

Descriptive statistics are listed in Table 5. The mean *PRICE* is NT\$4.475 million, and the mean *PRICE* adjusted using CPI is NT\$5.51 million, with a difference of approximately NT\$1 million from the unadjusted value, which can reflect the true value. The mean *AREA* is 46.16 ping, and the mean *AGE* is 24.7 years. The minimum and maximum values of the variables related to the living environment are 1 and 5, respectively, and the mean values are 3.789, 3.481, 3.883, and 3.041 for *INSIDE*, *OUTSIDE*, *CONV*, and *SATI*, respectively. These mean values are all higher than 3. This result indicates that most of the houses in the six municipalities in Taiwan are located in areas convenient for daily life activities. In addition, the quality of life variable (*QUAL*) transformed using PCA is a continuous variable with a mean value of 0, and the minimum and maximum values are -6.703 and 3.837, respectively.

To examine whether *INSIDE*, *OUTSIDE*, *CONV*, and *SATI* are related to *AREA* and *AGE*, pairwise correlation is performed. The correlation coefficients of the four variables pertaining to satisfaction with living quality and *AREA* and *AGE* range from -0.037 to 0.09 and from -0.177 to 0.026, respectively, indicating that the correlation between the level of satisfaction with living quality and housing characteristics (house area and age) is extremely low. Moreover, buildings with 1–5 floors have 6224 households (72.71% of the total number of floors), buildings with 6–10 floors have 851 households (9.94% of the total number of floors), and buildings with 11 floors and more have 1485 households (17.35% of the total number of floors). Regarding the distribution by residential area, the numbers of the participants living in Taipei City, New Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, and other counties and cities are 576, 1482, 832, 982, 650, 906, and 3375 households, accounting for 6.18%, 16.82%, 9.52%, 11.07%, 7.37%, 10.4%, and 38.63%, respectively. These findings indicate that the distribution of residents is slightly lower in Taipei City, and the percentage is almost the same as that in various regions of Taiwan. In terms of *CYCLE*, 5540 (63.14%) residential houses were purchased or built during the economic contraction period, and 3263 houses (36.86%) were purchased or built during the economic expansion period.

Table 5. Descriptive statistics

Variables	Average(Median)	Minimum	Maximum
Housing price	447.5(350)	1	10000
Housing price (adjusted using CPI)	551(444.15)	5.61	16184.77
House area	46.16(40)	11	499
House age	24.7(24)	0	56
Living quality	0(0.073)	-6.707	3.825
The indoor living environment	3.793	1	5
The outdoor living environment	3.486	1	5
Living convenience level	3.885	1	5
Living satisfaction level	3.043	1	5



Variables(category variable)	category	frequency	percent
The total number of floors	Floor1-5(0)	6224	72.71%
	Floor 6-10(1)	851	9.94%
	Above the 11th(2)	1485	17.35%
Residential area	Taipei City(1)	529	6.18%
	New Taipei City(2)	1440	16.82%
	Taoyuan City(3)	815	9.52%
	Taichung(4)	948	11.07%
	Tainan City(5)	631	7.37%
	Kaohsiung City(6)	890	10.40%
	Other counties and cities(7)	3307	38.63%
Economic cyclevariable	Systolic period(0)	5405	63.14%
	Expansion period(1)	3155	36.86%

#### 4.2 Analysis of Empirical Results

Considering the urban–rural differences, the variable pertaining to the residential area is analyzed across Taiwan overall and by each region.

##### 4.2.1 Analysis of Survey Data Across Taiwan Overall

The results of the analysis of the data for Taiwan overall are shown in Table 6. The adjusted coefficient of determination of Model 1 is 0.346, which confirms that this model fit has favorable explanatory power. The adjusted coefficient of determination of Model 2 is 0.354, denoting an increase of 0.008 in explanatory power compared with that explained by Model 1. This result indicates no difference in the explanatory power of Models 1 and 2 for housing prices. The difference of Model 2 from Model 1 is attributed to the interaction effect of the *CYCLE* term, where the interaction terms of *CYCLE* with *AGE* and *AGE*<sup>2</sup> are significant, but the remaining interaction terms are mostly nonsignificant. If the analysis focuses on economic cycle–related issues, Model 2 is recommended. Nonetheless, the main study focus is to explain housing prices. If the difference between the two models is small, Model 1 is recommended according to the parsimony principle.

Main variables such as *AREA*, floor number, and *BTYPE* estimated by the Model 1 are consistent with the expected direction and attain significance. The coefficient of 0.008 for *AREA* denotes that the housing price is higher when the house area is larger (Lee et al., 2012). In terms of *BTYPE*, residential buildings with 6–10 floors (coefficient = 0.209) and 11 floors or more (coefficient = 0.167) are more expensive than residential buildings with only 1–5 floors. In terms of *AGE* and *AGE*<sup>2</sup>, the scatter plot of the housing price and previous analysis results reveal that the housing price decreases as house ages. Therefore, the expected direction of *AGE* is negative, and the effect is even lower when a quadratic term is added for adjustment; thus, the expected effect of *AGE*<sup>2</sup> is positive. The coefficients of *AGE* and *AGE*<sup>2</sup> are –0.046 and 0.0003576, respectively; both coefficient terms are significant. This observation implies that for every 1-year increase in the age of the house, the housing price will decrease by 4.6%. However, with an increase in time, the prices in the early period will fall faster but at a progressively slower pace; thus, this variable can capture changes between real estate price patterns (Malpezzi et al., 1987; Goodman & Thibodeau, 1995; Goodman & Thibodeau, 1997; Smith, 2004; Wilhelmsson, 2008).

In a comparison of the six municipalities with other counties and cities, with Taipei City as the benchmark, the coefficient values for the other five municipalities and the other counties and cities are all negative and significant. This result is reasonable. In addition, the coefficient reflects the difference in housing prices among the municipalities, with the highest housing prices found for Taipei City, followed by New Taipei City (coefficient = –0.430), Taichung City (coefficient = –0.661) and Kaohsiung City (coefficient = –0.694), Taoyuan City (coefficient = –0.723), and Tainan City (coefficient = –0.835), and the lowest housing prices are found for the other counties and cities (coefficient = –0.919). In terms of living environmental quality variables, a coefficient of 0.056 indicates that modern people pay more attention to interior landscape and decoration of their homes and convenience in daily life, and that they are more willing to pay higher housing prices. Moreover, the empirical results of *CYCLE* demonstrate that housing prices in the economic expansion period (coefficient = 0.050) outperform those in the economic contraction period, but the coefficient value is low. Notably, the *CYC:QUALITY* coefficient of –0.018 in Model 2 is not significantly different from 0, indicating that the positive effect of *QUAL* on housing prices does not differ in the economic expansion or contraction period.

Table 6. Inferential statistical analysis of possible factors affecting housing prices

variable	Model 1: MAIN				Model 2: WITH INTERACTION			
	Estimate	Std. Error	p-value	Sig.	Estimate	Std. Error	p-value	Sig.
<i>INTERCEPT</i>	7.067	0.047	<0.001	***	7.133	0.053	<0.001	***
<i>AREA</i>	0.008	0.000	<0.001	***	0.008	0.000	<0.001	***
<i>AGE</i>	-0.046	0.002	<0.001	***	-0.049	0.002	<0.001	***
<i>AGE</i> <sup>2</sup> §	0.000	0.000	<0.001	***	0.000	0.000	<0.001	***
<i>BTYPE1</i>	0.209	0.028	<0.001	***	0.159	0.028	<0.001	***
<i>BTYPE2</i>	0.167	0.025	<0.001	***	0.138	0.025	<0.001	***
<i>CITY2</i>	-0.430	0.036	<0.001	***	-0.417	0.043	<0.001	***
<i>CITY3</i>	-0.723	0.040	<0.001	***	-0.657	0.049	<0.001	***
<i>CITY4</i>	-0.661	0.039	<0.001	***	-0.651	0.047	<0.001	***
<i>CITY5</i>	-0.835	0.043	<0.001	***	-0.882	0.052	<0.001	***
<i>CITY6</i>	-0.694	0.039	<0.001	***	-0.717	0.047	<0.001	***
<i>CITY7</i>	-0.919	0.034	<0.001	***	-0.941	0.040	<0.001	***
<i>QUALITY</i>	0.056	0.006	<0.001	***	0.062	0.007	<0.001	***
<i>CYCLE</i>	0.050	0.016	0.002	**	-0.547	0.108	<0.001	***
<i>CYC:AREA</i>	---	---	---	---	0.000	0.001	0.514	---
<i>CYC:AGE</i>	---	---	---	---	0.071	0.007	<0.001	***
<i>CYC:AGE</i> <sup>2</sup>	---	---	---	---	-0.002	0.000	<0.001	***
<i>CYC:CITY2</i>	---	---	---	---	-0.066	0.080	0.409	---
<i>CYC:CITY3</i>	---	---	---	---	-0.181	0.087	0.037	*
<i>CYC:CITY4</i>	---	---	---	---	-0.078	0.085	0.357	---
<i>CYC:CITY5</i>	---	---	---	---	0.056	0.091	0.542	---
<i>CYC:CITY6</i>	---	---	---	---	-0.002	0.085	0.985	---
<i>CYC:CITY7</i>	---	---	---	---	0.006	0.076	0.935	---
<i>CYC: QUALITY</i>	---	---	---	---	-0.018	0.011	0.121	---
<i>R</i> <sup>2</sup>	0.347				0.356			
<i>R</i> <sub>adj</sub> <sup>2</sup>	0.346				0.354			

\*\*\* denotes <0.001; \*\* denotes <0.01; \* denotes <0.05; and · denotes <0.1

§. The coefficients are 0.0003576 and 0.0004228, respectively.

#### 4.2.2 Data Analysis of the Six Municipalities and Nonmunicipal Areas

The effect of rural–urban differences on housing prices is analyzed using the regression model that includes the six municipalities and the nonmunicipal areas. The analysis results for seven residential areas in the six municipalities and the nonmunicipal areas are listed in Table 7 (Model 1: main effect) and Table 8 (Model 2: main effect and interaction between economic cycle factors). The adjusted coefficients of determination of the main effect (Model 1) and the interaction with some factors (Model 2) range between 0.249 and 0.393 and 0.270 to 0.398, respectively, with minor differences between the models. The lowest coefficient is 0.005 in New Taipei City, and the highest coefficient is 0.05 in Taoyuan City. Therefore, Model 1 is recommended for illustrating the relationship between various variables and housing prices.

The results in Table 7 reveal that the coefficients for different residential areas are in the same direction as presented in Table 1. The coefficient of *AREA* is positive, indicating that the housing price is higher with a larger area of the house. The coefficient of *AGE* is negative, indicating that a higher house age is associated with a lower housing price; the coefficient of *AGE*<sup>2</sup> is positive, indicating that the housing price decreases with a higher house age, but the rate of decline is slow. However, the results for Taoyuan City, Taichung City, and Tainan City are nonsignificant. The *BTYPE* values for Taipei City, New Taipei City, Taichung City, and Kaohsiung City are all positive, indicating that buildings with more floors have higher housing prices than buildings with 1–5 floors. The *QUAL* values, except that for Taipei City (which has a negative but nonsignificant value), for the other six residential areas are all positive and significant (except that for Kaohsiung City). This result is consistent with the conclusion of Goetzmann and Spiegel (1997) that living quality is influenced by the surrounding environment and building characteristics, and the improvement of living quality has a positive effect on housing prices. *CYCLE* varies greatly in different areas, but only the results for Taoyuan City, Kaohsiung City, and nonmunicipal areas are significant, and the coefficients for Kaohsiung City and the nonmunicipal areas are positive, indicating that a prosperous economy will raise housing prices. Nevertheless, the coefficient for Taoyuan City is negative, indicating that *PRICE* and *CYCLE* are negatively correlated. Furthermore, the

coefficients for Kaohsiung City and the nonmunicipal areas are positive, indicating that during an economic boom, people will have a higher budget to buy houses, which will increase housing prices. Taipei City, New Taipei City, Taoyuan City, Taichung City, Tainan City, Kaohsiung City, and other counties and cities

Table 7. Inferential statistical analysis of possible factors affecting housing prices (Model 1: MAIN)

<i>variable</i>	Taipei City	New Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City	other counties and cities
<i>INTERCEPT</i>	6.947***	6.305***	6.397***	6.327***	5.995***	6.175***	6.315***
<i>AREA</i>	0.016***	0.012***	0.009***	0.009***	0.010***	0.011***	0.006***
<i>AGE</i>	-0.062***	-0.041***	-0.036***	-0.035***	-0.032***	-0.047***	-0.051
<i>AGE</i> <sup>2</sup>	0.0007**	0.0004*	0.00015	0.00015	0.00012	0.0005***	0.00044***
<i>BTYPE1</i>	0.405***	0.308***	0.161***	0.129***	-0.034	0.327***	0.151*
<i>BTYPE2</i>	0.308*	0.397***	-0.115	0.087***	-0.067	0.275***	0.229***
<i>QUALITY</i>	-0.012	0.027*	0.049**	0.062***	0.052**	0.016	0.087***
<i>CYCLE</i>	0.048	0.034	-0.139**	0.009	0.093	0.100*	0.112***
<i>R</i> <sup>2</sup>	0.259	0.396	0.299	0.348	0.360	0.303	0.309
<i>R</i> <sub>adj</sub> <sup>2</sup>	0.249	0.393	0.293	0.343	0.353	0.297	0.308
Number of samples	529	1440	815	948	631	890	3307

\*\*\* denotes <0.001; \*\* denotes <0.01; \* denotes <0.05; and · denotes <0.1.

Table 8. Inferential statistical analysis of possible factors affecting housing prices (Model 2: WITH INTERACTION)

<i>variable</i>	Taipei City	New Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City	other counties and cities
<i>INTERCEPT</i>	7.301***	6.361***	6.697***	6.418***	6.058***	6.309***	6.254***
<i>AREA</i>	0.015***	0.012***	0.006***	0.008***	0.009***	0.010***	0.007***
<i>AGE</i>	-0.083***	-0.044***	-0.048***	-0.041***	-0.032***	-0.053***	-0.050***
<i>AGE</i> <sup>2</sup>	0.001+	0.0004***	0.0003***	0.0003*	0.0001	0.0005***	0.00045***
<i>BTYPE1</i>	0.404***	0.257***	0.028	0.095***	-0.109	0.324***	0.103
<i>BTYPE2</i>	0.341*	0.349***	-0.160*	0.052***	-0.100	0.273***	0.240***
<i>QUALITY</i>	-0.056	0.037**	0.052*	0.092***	0.049*	0.013	0.095***
<i>CYCLE</i>	-1.573***	-0.304	-1.875	-0.580	-0.732**	-0.382	-0.184
<i>CYC:AREA</i>	-0.002	-0.001***	0.006***	0.003*	0.002	0.003	-0.002*
<i>CYC:AGE</i>	0.139**	0.049***	0.156***	0.054**	0.086***	0.026	0.061***
<i>CYC:AGE</i> <sup>2</sup>	-0.003**	-0.001***	-0.003***	-0.001**	-0.002***	0.000	-0.002***
<i>CYC: QUALITY</i>	0.162*	-0.032	-0.010	-0.063*	-0.003	0.009	-0.023
<i>R</i> <sup>2</sup>	0.285	0.402	0.354	0.361	0.381	0.306	0.319
<i>R</i> <sub>adj</sub> <sup>2</sup>	0.270	0.398	0.345	0.353	0.370	0.297	0.317
Number of samoles	529	1440	815	948	631	890	3307

\*\*\* denotes <0.001; \*\* denotes <0.01; \* denotes <0.05; and · denotes <0.1.

## 5. Conclusions and Recommendations

The 2015 Report on the Housing Status Survey conducted by the Construction and Planning Agency, Ministry of the Interior is the most detailed, representative, and recent survey on residence issues in Taiwan. In the survey, satisfaction with the living environment is divided into four types: satisfaction with the convenience in daily life, surrounding outdoor environment, indoor living environment, and outdoor living environment. To avoid possible model estimation bias caused by the selection of explanatory variables, this study employs PCA to construct a living quality satisfaction variable for the first time, and its explanatory power for housing prices is explored. This study also explores the effect of living environment conditions on housing prices. Adopting PCA is necessary because the aforementioned four types of items have a high correlation with each other, which can easily lead to errors in the results. Numerous studies that have investigated the relationship between housing prices and the environment by using questionnaires have demonstrated the problem of variable selection. This is the first attempt in real estate research at home and abroad aiming to effectively solve the problem of variable selection in regression models, and the verification results will provide a more consistent interpretation.

In addition to the aforementioned collinearity problem, the results of this study have the following essential applications and implications in the literature and practice:

1) As shown in the literature, compared with residents in urban periphery and nonurban areas, residents in municipal areas pay more attention to environmental quality. Studies have also discovered that the maturity and convenience of environmental facilities are the primary factors that contribute to the price difference of commercial residential buildings between cities. This study conducts subsample analysis of the data of municipalities and nonmunicipal areas, the results of which can determine the differences in urban development and the living environment quality in various locations, thereby resulting in differences in housing prices.

2) The residential housing market is not a perfectly competitive market, and each residential unit has its own heterogeneity. Relevant studies have demonstrated that differences in the degree of urban development may affect residents' requirements and expectations for living quality and further affect housing prices. This study shows that residents of the six municipalities, such as New Taipei City, Taoyuan City, Taichung City, and Tainan City, as well as nonmunicipal areas, are willing to pay higher housing prices to obtain or use facilities that can improve their living quality. The study results can be used as a reference by real estate companies to understand the public's perception of how living quality affects housing prices. Real estate developers should implement product positioning and market segmentation according to living environmental factors in building and planning phases.

3) The government formulates housing legislations and policies in accordance with the Housing Act. When establishing and implementing living standards, the government should pay more attention to improving the quality of the living environment through measures such as subsidizing local governments to improve the quality of the living environment and promoting the construction and planning of public facilities focusing on environmental quality.

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