INTERNATIONAL REAL ESTATE REVIEW

2022 Vol. 25 No. 2: pp. 199 – 216

Vertical Housing Price Gradient and Ground Floor Premium in Taipei City

Yu-Hui Chen
Department of Real Estate and Built Environment, National Taipei University. Email: yhcc97@gmail.com.

Chien-Wen Peng
Department of Real Estate and Built Environment, National Taipei University. Email: cwpeng@mail.ntpu.edu.tw.

Chung-Hsien Yang
Department of Real Estate Management, National Pingtung University. Email: turtlekk@mail.nptu.edu.tw.

This study aims to examine the influence of the floor level on housing prices based on the vertical dimensions of the building. A two stage least squares regression (2SLS) and two stage quantile regression (2SQR) are utilized to analyze the urban regions in Taipei City by using data obtained from the online actual price registry of real estate transactions from August 2012 to April 2020. After considering the spatial autocorrelation, the following conclusions are reached. First, in addition to the ground floor, the floor level premium is 0.55% for residential buildings with an elevator, and the premium increases when the housing price quantile increases. However, for walk-up apartments, there is a floor level discount of -4.21%, and the price discount increases when the quantile for the housing price increases. Secondly, when compared to the other floors, the ground floor premium is 9.61% for residential buildings with an elevator, which is a little higher than walk-up apartments for which the ground floor premium is 8.54%. The results reveal that the influence of the type of residential building and the total number of floors on the ground floor premium is not as high as expected. Finally, regardless of whether the residential buildings have an elevator or are walk-up apartments, the ground floor premium increases when the housing price quantile increases. The ground floor premiums for residential buildings with an elevator range from 7.30% to 11.85%. They are a little higher than those for walk-up apartments which range from 6.25% to 9.69%.

Keywords

Bid rent, Floor level price premium, Vertical price gradient, Ground floor, Spatial quantile regression

1. Introduction

As real estate is physically immobile, location can be viewed as the most important factor that affects its value. Alonso (1964) states that, in accordance with the Ricardian rent theory, the location of land in a single central city affects transportation and commuting costs. Different land users have different degrees of willingness to pay rent for land in specific locations. The spatial distribution, in terms of the various types of land use, is mainly determined by the distance of a building from the city center (accessibility). This has constituted as the foundations of the bid rent theory that mapped the future of real estate economics.

Urban life has the advantages of providing more consumption and employment options. Urban life provides a better educational environment and more amenities, as well as offers higher incomes. With the huge gap between urban and rural developments, urbanization has become an important global development trend. The proportion of urban population to total population was 34% in 1960, which increased to 56% in 2020. It is expected that 68% of the world population is projected to live in urban areas by 2050.[1]The demand for urban land is high yet supply is relatively scarce. This dilemma is even more obvious in Asia, where many urban areas are densely populated. As the traditional urban growth pattern which is horizontal in expansion towards the suburbs is now evolving into a vertical growth pattern, the concept of location not only refers to the distance from the city center, but also extends to the vertical distance from the ground floor to other floors above.

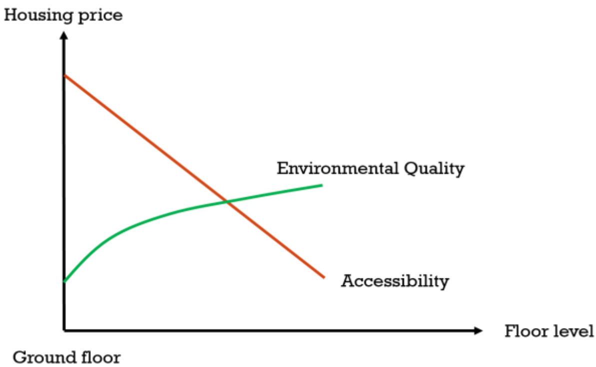
The value of a location, according to the bid rent theory, is mainly based on the savings in transportation/commuting costs. The willingness of potential land users to pay rent will be reduced as the distance from the city center increases. The bid rent curve basically has a negative slope. However, from the perspective of vertical location, there are many factors that affect the willingness of users to pay for rent on different floors. Factors such as commercial aggregation (flexibility of use), accessibility, and the ability to escape to safety will make the price for lower floors relatively higher. Conversely, environmental quality factors such as reduced noise/air pollution, privacy, lighting, ventilation, and landscape will result in higher housing prices

---

[1] The data source is from the United Nations website: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

for higher floors. The two influences move in opposite directions, and the vertical rent curve may be nonlinear. The net impact will vary due to the different temporal and spatial factors (see Figure 1).

Figure 1 Influence of Floor Level on Housing Prices: Accessibility vs. Amenities



As many cities continue to develop vertically and the number of high-rise buildings continues to increase, the theoretical construction and empirical analysis of the vertical floor premium has become a very important consideration in decision making in the real estate market. Studies on the location value of urban land or real estate based on the bid rent theory are already quite abundant (Alonso, 1964; Mills, 1967; Muth, 1969; Colwell and Sirmans, 1978; Kau and Sirmans, 1979; Ohkawara, 1985; Coulson and Engle, 1987; McMillen, 1996; Gibbons and Machin, 2005; Ahlfeldt and Wendland, 2013). However, earlier studies on the housing price or rent for vertical dimensions are relatively rare (Wong et al., 2011; Conroy et al., 2013; Danton and Himbert, 2018; Liu et al., 2018; Nase et al., 2019). As there are still many considerations for improving the theoretical or empirical robustness of the price/rent gradient of vertical housing, this study seeks to examine the influence of the floor level on housing prices from the aspect of the vertical dimensions of a building.

The remainder of this paper is organized as follows. Section 2 of this study provides a literature review, which mainly focuses on the empirical literature related to the bid rent theory and the factors that affect the floor level price/rent premium. Section 3 covers the research design and explains the current condition of the research scope, empirical data, and the application of the empirical model. Section 4 offers and discusses the results of the empirical analysis. The final section presents the conclusions and recommendations.

2. Literature Review

Alonso (1964) points out that in a single city center, each piece of land can be used for multiple purposes. The potential competitors have different levels of willingness to pay for land in a specific location. The user and its use will be determined based on who is willing to pay the highest rent. Therefore, depending on the ability of the potential land users to pay the land rent, the location and the patterns of urban land use are determined. Without land use zoning controls, the distance from the city center will affect transportation or commuting costs. Therefore, the rent for land closer to the city center is usually higher, and will decrease with distance from the city center, thus exhibiting a negative slope.

DiPasquale and Wheaton (1996) argue that the rent for urban land has two components. One is the rent for agricultural land on the edge of the city, and the other is the location rent (equal to the commuting cost that can be saved at the location). The location rent is positively related to the size of the city and transportation costs, and negatively related to the distance from the city center and the amount of land used per housing unit. As the city continues to grow and expand outwards, the location rent of the land inside the city will also increase. In addition, many scholars have further explored the factors that affect urban land use patterns, especially the impact of improved transportation systems (such as highways, railways, and MRT systems) on land use patterns and land rent gradient curves (Mills, 1967; Muth, 1969; Colwell and Sirmans, 1978; Kau and Sirmans, 1979; Ohkawara, 1985; Coulson and Engle, 1987; McMillen, 1996; Gibbons and Machin, 2005; Ahlfeldt and Wendland, 2013).

Nowadays, land use patterns have progressed from horizontal to vertical dimensions. The concept of location not only refers to the distance between the horizontally-oriented house and the city center, but also extends to the distance from the vertically-oriented ground floor to each floor above. However, most of the previous studies in the literature regard the floor level and building height as control variables that affect housing prices, with floor or floor squared (Mok et al., 1995; Chau et al., 2001; Ong et al., 2003; Sun et al., 2005), or by using dummy variables, such as high and low floors (So et al., 1997) or the ground and top floors (Dunse and Jones, 1998; Conroy et al., 2013). Only a few articles have conducted an in-depth analysis of the floor premium.

Wong et al. (2011) examine the impact of floor level and building height on housing price and find that the floor level premium is not constant, but declines with higher floor levels. There is no significant difference in the pattern of the floor level premium between high-rise and low-rise buildings. In addition, there is a positive and significant premium for units in low-rise buildings over those in high-rise ones. Conroy et al. (2013) examine whether there is a floor premium in high-rise residential buildings in San Diego, USA. The empirical results indicate that floor level premiums do exist, but increase at a decreasing rate. On average, the sales price of each additional floor increases by about 2.2%. Wen et al. (2020) find that road traffic externalities have a significant disamenity effect on property prices. However, the floor level has a significant moderating effect on the disamenity effect of road traffic, which also reveals a floor level premium in high-rise buildings.

In terms of the floor level rent premium of residential buildings, Danton and Himbert (2018) claim that accessibility and amenities are the main influences on rental price differences of floor level. The vertical rent curve is positive with respect to floor level. Moreover, the ground floor level has about 1.5-3.5% of the rental premium. This norm is more significant in high-priced housing regions. Helsley and Strange (2008) use the game theory to analyze the inherent value of the highest floor in a building. The dissipative competition over the prize for being the tallest creates much inefficient space and has a negative impact on the rent.

Nase et al. (2019) analyzed the vertical location rental price premium difference of tall office towers in Amsterdam. It is observed that a rental premium in higher floor locations does exist. For the vertical rent premium, 27% of the premium is related to the view, 3% is to industry-level differences, and the remaining 70% to firm-level signaling and other factors. Other than that, Liu et al. (2018) believe that tall commercial buildings constitute the skyline of urban cities. Due to the offset effect between accessibility and amenities, companies with high productivity would locate on higher floors, whereas companies with less productivity would locate on lower floors, and the ground floor is occupied by the retail sector. The vertical rent curve is therefore nonlinear.

It is obvious that the literature has turned discussions on bid rent from the horizontal to the vertical dimensions. Bid rent for horizontal land use is mainly based on the difference in commuting costs for different locations, while bid rent for vertical land use is based on the following important factors: accessibility, environment, and risk of defects and negative living conditions.

Accessibility is defined by distance to the ground floor. A unit has more accessibility in a building if it is closer to the ground floor. In the absence of an elevator, the price/rent will decrease with an increase in the number of floors, but the importance of accessibility will be significantly reduced with the use of elevators (Wong et al., 2011; Danton and Himbert, 2018). Two other important advantages can be derived from accessibility, namely, flexibility in use and the ability to escape to safety. If zoning regulations permit, the space on the ground floor may be used for retail in areas with more commercial activity. With the flexibility of both commercial and residential use, the willingness of buyers to pay will be higher. Furthermore, floors that are closer to the ground floor mean better means to escape, so the price/rent will also be higher.

The second factor, environment, is important because as the vertical distance from the ground floor increases, negative environmental externalities (such as noise, air pollution or mosquitoes) will be greatly reduced in severity and positive ones, such as privacy, amount of daylight, ventilation and view will usually be more prevalent. If the area has amenities that offer nice views, such as rivers, mountains, parks, squares, open spaces, etc., buyers are willing to pay higher prices for higher floor levels (Chau et al., 2001; Wong et al., 2011; Conroy et al., 2013; Danton and Himbert, 2018; Wen et al., 2020).

In addition to accessibility and environment, some floors may be more subject to the risk of defects and negative living conditions, and thus are discounted in price. For example, the top floor of a building may have the best view and most privacy, but is very warm due to direct sunlight or subjected to water leaks due to poor construction quality. Therefore, the price of the top floor may not the highest in a high-rise building. [2] If a building is equipped with a relay water tank and a mechanical or boiler room (including pressurized motors and generators) specifically in a mid to high floor level, the units on the same floor or above and below that floor will also result in a price discount due to noise or potential water leakage (Chau et al., 2001). Furthermore, people in different regions have preferences or dislikes of numbers which are usually seen as auspicious or unlucky. Numbers are also reflected in the prices that buyers are willing to pay for different floor levels. For example, the Taiwanese prefer the auspicious number 8, since 8 is synonymous the “fa” or making a fortune, while the number 4 tends to be disliked, because it has a similar sound to the word “death”. A builder in Taiwan would usually set the lowest price for the fourth floor (Lin et al., 2012).

There are many factors that affect the willingness of buyers to pay for a certain floor level as discussed, including commercial agglomeration (flexibility of use), accessibility, and the ability to escape to safety will render the price/rent of lower floors relatively high. Conversely, factors such as less noise/air pollution, more privacy, better lighting and ventilation, and a nice view will result in a higher price/rent for high floors. The influence of these factors on the willingness of buyers to pay differs, and so the net effect will vary in different areas.

As for the empirical methodology, most of the previous studies have used ordinary least squares (OLS) regression in their empirical work. However, some of these studies might have different results for certain explanatory variables in terms of the direction and degree of influence, and degree of significance. To examine whether the influence of the floor level on housing price will vary for different housing price quantiles, this study employs quantile regression (QR) for the empirical work. The application of QRs is becoming

---

[2] The top floor price discount phenomenon is quite common in some areas of mainland China.

increasingly popular in real estate research (Mak et al., 2010; Liao and Wang, 2012; Lin et al., 2012, Lin et al., 2014; Liao and Zhao, 2019; Feng et al., 2021).

Compared to OLS regressions, QRs are a nonparametric regression, and estimate conditional quantile functions, in which a quantile of the conditional distribution of a response variable is expressed as a function of the covariates. Different measures of central tendency and statistical dispersion can be useful to perform a more comprehensive analysis of the relationship between variables. QRs are therefore helpful for understanding outcomes that are non-normally distributed and have nonlinear relationships with response variables. Other important advantages of QRs include their superior capability to handle heteroscedasticity, outliers and unobserved heterogeneity (Liao and Wang, 2012).

Furthermore, housing prices often involve positive spatial autocorrelation, which means that the prices of geographically close units tend to be similar because of the spatial dependence of properties. Spatial econometric modelling therefore becomes necessary. This study will use Moran's I value to examine whether there is a spatial autocorrelation problem (Cliff and Ord, 1973; Dubin, 1998; Osland, 2010; Liao and Wang, 2012; Alter and Mahoney, 2021). If there is a spatial autocorrelation problem, we then adopt spatial econometrics for our empirical work.

3. Data and Description of Variables

3.1 Data Source

In this study, we consider Taipei City as the main empirical area because it is the capital city of Taiwan with the most investment in urban public construction. The data source is the real price registration data from an online real estate transaction inquiry service offered by the Ministry of the Interior. The total sample is 76,098 transactions for the period of October 2012 to April 2020.

The land use regulations of Taipei City stipulate that the main function of a residential district is to provide space for people to live in but also allows nonresidential activities to use the space, such as retail related to daily life necessities, services, and industries that cause the least public pollution. To some extent, the mixed use of land is allowed in residential districts only if the activities do not obviously conflict with residential use. This increases the flexibility in the use of some of the lower floor levels in a residential building and increases the willingness of buyers to pay, especially for the ground floor.

3.2 Model and Variables

The hedonic price model used in this study considers variables such as the characteristics of the housing unit itself, neighborhood and district environment, and transaction time. The empirical model adopts a logarithmic form, as follows:

$$\ln P_{idt} = \beta_0 + X_{it}\beta + \gamma_1 FL_{idt} * TYPE1 + \gamma_2 FL2_{idt} * TYPE1 + \gamma_3 GFL_{idt} * TYPE1 + \gamma_4 FL_{idt} * TYPE2 + \gamma_5 FL2_{idt} * TYPE2 + \gamma_6 GFL_{idt} * TYPE2 + \delta_d + \tau_t + \varepsilon_{idt} \quad (1)$$

where $\ln P_{idt}$ represents the transaction price of housing i in district d, and transaction time t in log form; β_0 represents the intercept term; X_{it} represents the housing or neighborhood characteristic of housing i at time t; β represents the coefficient matrix of the housing or neighborhood characteristics; δ_d represents the dummy variables of the district; τ_t represents the transaction time dummy variables; and ε_{idt} is the error term.

Table 1 Variables and their Definition

Variable	Definition
P	Price of the transacted housing unit per ping (1 ping =3.3 square meters)
FL	Number of floor levels of transacted unit
GFL	Ground floor
TFL	Total number of floors of building excluding basement
TYPE	Dummy for building type: residential buildings with elevator =1, walk up apartment =2
FL*TYPE	Interaction term for floor and building type
FL2*TYPE	Interaction term of floor square and building type
GFL * TYPE	Interaction term for ground floor and building type
SIZE	The unit's total construction area including private living area and shared area (ping)
SIZE2	Square of SIZE (ping)
AGE	Building age since obtaining usage permit (years)
AGE2	Square of AGE (year)
ZONE	Dummy for land use zone: residential zone=0, commercial zone=1
ROAD_W	Road width (meters)
ROAD_W2	Square of road width (meter)
$ROAD\_PR_j$	Dummy variables for housing price ranking based on located street of transacted unit: transaction price below the lowest 20th price quantile=0, other=1, j=1-3
DIST_MRT	Distance to the nearest MRT station, (kilometers)
DIST_PARK	Distance to the nearest park (kilometers)
DIST_SCHOOL	Distance to the nearest school (kilometers)
DIST_STORE	Distance to the nearest convenience store (kilometers)
$DISTRICT_j$	Dummy variable, 0 if the unit is in the lowest housing price district, 1 otherwise, j=1-11
$TIME_j$	Dummy variable, 0 if the unit's transaction time is in 2020Q1, 1 otherwise, j=1-29

To examine the price premium of the floor level and ground floor in different types of residential buildings and also the potential nonlinear relationships between floor level and housing price, we consider the interaction term of the floor level and building type (*FL*TYPE*), floor level square and building type (*FL2*TYPE*), and ground floor and building type (*GFL*TYPE*). As for the control variables, we include the area of the housing unit and its squared term (SIZE, SIZE2); building age and its squared term (AGE, AGE2); land use zoning (ZONE); road width and its squared term (ROAD_W, ROAD_W2); distance to the nearest MRT station (DIST_MRT), nearest MRT park (DIST_PARK), nearest school (DIST_SCHOOL), and nearest convenience store (DIST_STORE); and dummy variables for the administrative district ($DISTRICT_j$) and transaction time ($TIME_j$).

The mechanism to perform QRs is similar to that of ordinary regressions, where θ is the condition quantile, β=f(θ). The specification of the QR is as follows:

$$\begin{aligned}\ln P_{idt} = {} & \beta_0(\theta) + X_{\mathrm{it}}\beta(\theta) + \gamma_1(\theta)FL_{idt} * TYPE1 + \gamma_2(\theta)FL2_{idt} \\ & * TYPE1 + \gamma_3(\theta)GFL_{idt} * TYPE1 + \gamma_4(\theta)FL_{idt} * TYPE2 \\ & + \gamma_5(\theta)FL2_{idt} * TYPE2 + \gamma_6(\theta)GFL_{idt} * TYPE2 + \delta_d + \tau_t \\ & + \varepsilon_{idt}\end{aligned} \tag{2}$$

As for spatial econometric modelling, we follow Liao and Wang (2012) to use the 2SQR to deal with the spatial autocorrelation problem. We add a spatial-lag variable $\rho W \widetilde{\ln P_{idt}}$ in Equation (3), where ρis the coefficient of the spatial-lag variable, and W is a matrix of the spatial weight. In the first stage, the spatially lagged exogenous variables are regressed against the spatially lagged exogenous variables. The predicted $\widetilde{\ln P_{idt}}$ which is obtained from the first stage regression, is substituted for $\ln P_{idt}$ in the spatial -lag model to eliminate the correlation between the spatially lagged endogenous variable and the error term.

$$\begin{aligned}\ln P_{idt} = {} & \rho W \widetilde{\ln P_{idt}} + \beta_0(\theta) + X_{\mathrm{it}}\beta(\theta) + \gamma_1(\theta)FL_{idt} * TYPE1 \\ & + \gamma_2(\theta)FL2_{idt} * TYPE1 + \gamma_3(\theta)GFL_{idt} * TYPE1 \\ & + \gamma_4(\theta)FL_{idt} * TYPE2 + \gamma_5(\theta)FL2_{idt} * TYPE2 \\ & + \gamma_6(\theta)GFL_{idt} * TYPE2 + \delta_d + \tau_t + \varepsilon_{idt}\end{aligned} \tag{3}$$

4. Empirical Analysis

4.1 Empirical Results

Table 2 presents the descriptive statistics for the above variables. In addition to the average housing price, the housing characteristics for residential buildings with an elevator and those of walk-up apartments have some differences, especially in terms of AGE, SIZE, FL, and TFL.

This study uses the OLS and QR for the empirical work. However, the Moran's I value is 0.433, so there is an autocorrelation problem. Therefore, we adopt

2SLS and 2SQR to obtain further estimates. Table 3 shows the empirical results after correcting for the autocorrelation problem. From the adjusted R^2, the coefficients of spatial weight, and the significance level of the explanatory variables in 2SLS and 2SQR, we can confirm the goodness of fit of the models.

As for the floor level price premium of residential buildings with an elevator, the coefficient of *FL*TYPE1* is 0.0055, which reaches the 1% significance level. This means that, excluding the ground floor, the housing price will increase by 0.55% with each higher floor. From the low to high housing price quantiles, the extent of the influence of the floor level on the housing price ranges from 0.31% to 0.89%. This shows that, as the housing price increases, the buyers are willing to pay more for higher floor levels. However, the coefficients of the floor level squared terms (*FL2*TYPE2*) for the 10th, 25th, and 50th quantiles are not significant even at the 10% significance level. The coefficients of the floor level squared terms are negative and significant at the 1% significance level for the 75^{th} and 90^{th} quantiles. This means that the floor level price premium will increase at a decreasing rate as the floor level increases in the high housing price quantiles, but this phenomenon is not obvious in the mid and low housing price quantiles (see Figure 2).

Table 2 Basic Statistics

Residential buildings with an elevator	**Mean**	**SD**	**Min.**	**Max.**
P (NT$ 10 thousand)[3]	64.77	18.86	16.47	156.44
P (Ln)	4.13	0.30	2.80	5.05
SIZE (ping)	36.86	16.68	5.10	172.91
AGE (year)	19	14	1	53
TFL (floor)	11	4	3	42
FL (floor)	7	4	2	29
ROAD_W (m)	8	3	1	40
DIST_MRT (km)	0.561	0.441	0.009	4.624
DIST_STORE (km)	0.124	0.097	0.002	0.947
DIST_SCHOOL (km)	0.303	0.170	0.002	1.378
DIST_PARK (km)	0.170	0.093	0.011	0.825
Walk-up apartments	**Average**	**Std. Dev.**	**Min.**	**Max.**
P (NT$ 10 thousand)	48.94	14.40	16.07	208.70
P (Ln)	3.85	0.28	2.78	5.34
SIZE (ping)	28.42	6.97	6.03	70.90
AGE (year)	39	8	1	60
TFL (floor)	5	1	2	5
FL (floor)	3	1	2	5
ROAD_W (m)	7	3	1	38
DIST_MRT (km)	0.652	0.480	0.014	4.485
DIST_STORE (km)	0.123	0.112	0.01	2.093
DIST_SCHOOL (km)	0.293	0.155	0.02	1.337
DIST_PARK (km)	0.168	0.10	0.01	1.608

[3]US$1 = NT$27-29

Table 3 2SLS and 2SQR estimates of the spatial lag model

Variables	2SLS	0.1	0.25 qua.	0.5	0.75	0.90
CONST	1.52669**	1.5108***	1.3559***	1.505***	1.6641***	1.7744***
	(0.03252)	(0.0614)	(0.0435)	(0.0394)	(0.0387)	(0.0503)
SIZE1	-0.004528***	-0.0048***	-0.0043***	-0.0042***	-0.0052***	-0.0059***
	(0.000147)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0003)
SIZE2	0.000037***	0.000038***	0.000036***	0.000032***	0.00004***	0.00005***
	(0.000002)	(0.000002)	(0.000002)	(0.000003)	(0.000001)	(0.000002)
AGE	-0.013893***	-0.014***	-0.0139***	-0.0138***	-0.0136***	-0.0139***
	(0.000152)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0003)
AGE2	0.000188***	0.0002***	0.0002***	0.0002***	0.0002***	0.0002***
	(0.000003)	(0.000003)	(0.000003)	(0.000003)	(0.000003)	(0.000003)
TFL	-0.000551**	-0.0014***	-0.0005	-0.0006*	-0.0002	-0.0009***
	(0.000218)	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
FL* TYPE1	0.005498***	0.0031**	0.0043***	0.0056***	0.0066***	0.0089***
	(0.000651)	(0.0013)	(0.001)	(0.0008)	(0.0007)	(0.0009)
FL2* TYPE1	-0.000079**	0.0001	0.00003	-0.0001	-0.0001***	-0.0003***
	(0.000039)	(0.0001)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
GFL* TYPE1	0.096135***	0.079***	0.073***	0.0952***	0.1171***	0.1185***
	(0.004268)	(0.007)	(0.0074)	(0.0056)	(0.0057)	(0.0061)
FL* TYPE2	-0.042136***	-0.0405***	-0.0333***	-0.0373***	-0.049***	-0.0552***
	(0.002065)	(0.0041)	(0.003)	(0.0026)	(0.0025)	(0.0028)
FL2* TYPE2	0.00394***	0.0033***	0.002***	0.0031***	0.0053***	0.0065***
	(0.000384)	(0.0007)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
GFL* TYPE2	0.085421***	0.0625***	0.0774***	0.0879***	0.0941***	0.0969***
	(0.003816)	(0.0079)	(0.0047)	(0.0051)	(0.0053)	(0.0054)
ROAD_W	0.002995***	0.0018	0.0017**	0.0019***	0.0036***	0.0053***
	(0.000569)	(0.0012)	(0.0008)	(0.0006)	(0.0006)	(0.0007)
ROAD_W2	-0.000072**	-0.00004	-0.00004	-0.00004	-0.0001***	-0.0002***
	(0.000029)	(0.0001)	(0.00001)	(0.00001)	(0.00003)	(0.00003)
ZONE	-0.023545***	-0.0236***	-0.0274***	-0.0217***	-0.0227***	-0.0181***
	(0.001492)	(0.003)	(0.0024)	(0.002)	(0.0018)	(0.0022)
ROAD_PR1	0.088759***	0.0926***	0.0974***	0.0922***	0.0864***	0.0783***
	(0.001601)	(0.0029)	(0.0022)	(0.0021)	(0.0021)	(0.0024)
ROAD_PR2	0.158833***	0.1645***	0.1719***	0.1647***	0.1533***	0.1376***
	(0.001674)	(0.0029)	(0.0025)	(0.0022)	(0.0021)	(0.0024)
ROAD_PR3	0.210216***	0.21***	0.22***	0.2191***	0.2067***	0.1923***
	(0.001873)	(0.0034)	(0.0028)	(0.0023)	(0.0024)	(0.0027)

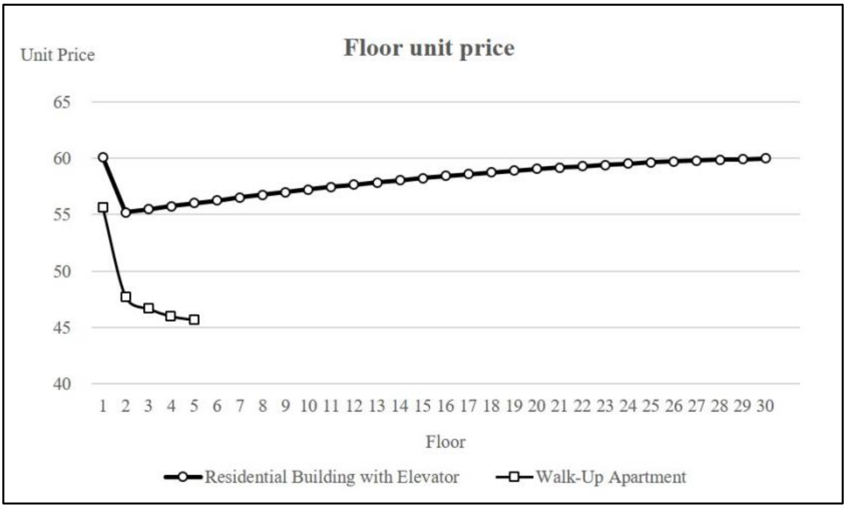
(Continued…)

(Table 3 Continued)

DIST_ MRT	-0.061482*** (0.001555)	-0.0686*** (0.0031)	-0.0647*** (0.0021)	-0.0615*** (0.0019)	-0.058*** (0.0021)	-0.0547*** (0.0023)
DIST_ PARK	-0.030086*** (0.005973)	-0.0138 (0.0104)	-0.0029 (0.0078)	-0.0209*** (0.0075)	-0.0322*** (0.0073)	-0.0531*** (0.0095)
DIST_SCHOOL	-0.080882*** (0.003606)	-0.0755*** (0.0067)	-0.0857*** (0.005)	-0.0817*** (0.0045)	-0.0855*** (0.0049)	-0.0846*** (0.0056)
DIST_ STORE	-0.158636*** (0.006026)	-0.1882*** (0.0112)	-0.1744*** (0.0085)	-0.1578*** (0.0093)	-0.1497*** (0.007)	-0.1485*** (0.0082)
$W\widetilde{\ln P_{idt}}$	0.6606***	0.6183***	0.6797***	0.6655***	0.6538***	0.6519***
District	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Time	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Adj R2/Pseudo R2	0.761	0.49931	0.51271	0.51653	0.51982	0.5168

Notes: 1. Standard errors are in parentheses. 2. ***, ** and * indicate that the coefficient is significant at the 1%, 5%, and 10% significance levels, respectively.

Figure 2 Vertical Price Gradient of Residential Buildings with an Elevator vs. Walk-up Apartments



Note: Housing price in NT$ 10 thousand/per ping. 1 ping = 3.3 square meters. US$1 = NT$27-29

From the perspective of walk-up apartments, there is a floor-level price discount instead of a floor-level price premium. The coefficient of *FL*TYPE2* is -0.0421 and reaches the 1% significance level. This means that, excluding the ground floor, the housing price will decrease by 4.21% with each higher floor. This might be due to the low accessibility for higher floor levels in the walk-up apartments. From the low to high housing price quantiles, the extent of the influence of the floor level on the housing price ranges from -4.1% to -5.5%. Except for the 10th quantile, this indicates that as the housing price increases, the buyers are only willing to pay less for higher floor units. In addition, the coefficients of the floor level squared terms (*FL2*TYPE2*) are positive and significant at the 1% significance level for all quantiles.

This means that the floor level price discount will increase at an increasing rate with higher floors for all housing price quantiles. As for the interaction term for the ground floor and the building type, the coefficient of *GFL*TYPE1* is 0.0961 and significant at the 1% significance level. This means that there is a 9.61% price premium for the ground floor compared to the other floors in residential buildings with an elevator. From the results of the 2SQR, the coefficients for the impact of the ground floor on the housing price from the low to high housing quantiles are found to range from 7.30% to 11.85%. This shows that the ground floor price premium will increase as housing prices increase.

The coefficient of *GFL*TYPE2* is 0.0854 and significant at the 1% significance level. This means that there is an 8.54% price premium for the ground floor compared to the other floors in residential buildings with an elevator. Based on the results of the 2SQR, the coefficients for the impact of the ground floor on the housing price from the low to high housing quantiles range from 7.30% to 11.85%. This also shows that the ground floor price premium will increase as housing prices increase. Furthermore, the ground floor premium between residential buildings with an elevator and walk-up apartments is only 1% to 2%. It seems that the influence of the building type or building height on the ground floor is not very obvious.

4.2 Discussion

This study discusses the vertical price gradient by examining the floor level premium/discount for different types of residential buildings. The transportation cost is the core factor that underlies the traditional horizontal price/rent gradient based on the bid rent theory. Even though accessibility is still an important consideration for the vertical price/rent gradient, nevertheless, the use of an elevator greatly reduces its importance. Conversely, the environment or nearby amenities will increase in importance as the distance from the ground floor increases, and there is a floor level premium.

Previous studies related to the price/rent differences for each floor level, such as Wong et al. (2011), Conroy et al. (2013), and Wen et al. (2020), all confirm the existence of a floor level premium. Not only do these studies find that the floor-level premium is not constant, but that it also decreases with more floors in a building. The empirical results of this study for residential buildings with an elevator are very similar to those of previous studies. However, from the results of our spatial QR, the phenomenon that the floor level premium decreases as the height of the building increases only exists at the 75th and 90th price quantiles, and is not found for the middle and lower price quantiles. Furthermore, Conroy et al. (2013) finds that the floor level premium is about 2.2% and much higher than the 0.55% in our model, which shows an obvious national or cultural difference.

Discussions on ground floor premium are relatively few in previous studies. Danton and Himbert (2018) find that the rent premium of the ground floor is around 1.5% to 3.5%, and increases as the housing price increases. In our study, the ground floor price premiums are 9.61% and 8.54% in residential buildings with an elevator and walk-up apartments, respectively. There is a 5 to 8 percentage point difference for the ground floor premium between our result and that of Danton and Himbert (2018), which might be due to the difference between the housing price and rent, or different land use regulation systems. Furthermore, we find that the influence of the building type or building height on ground floor premium is not obvious. This phenomenon has not been well discussed in previous studies. We argue that the value of the ground floor is mainly influenced by the neighborhood environmental quality instead of the housing characteristics.

Liu et al. (2018) and Nase et al. (2019) provide very similar findings in which a higher floor level does not merely reflect the value of better amenities, but also the economic ability, competitiveness, social status, and preference or taste of the buyers or users. Limited by the data source, we can only obtain the characteristics of the housing unit, building, and neighborhood. It would be worthwhile to further study the impact of the characteristics of buyers or users on the floor level price/rent premium in the future if at all possible.

5. Conclusions

This study has sought to examine the influence of the floor level on housing prices from the aspect of the vertical dimensions of the building. After considering spatial autocorrelation, the following conclusions are reached.

First, in addition to the ground floor, the floor level premium is 0.55% for residential buildings with an elevator, and the premium increases when the quantile of the housing price increases. However, for walk-up apartments, there is a floor level discount of -4.21%, and the price discount increases when the housing price quantile increases.

Secondly, compared with other floors, the ground floor premium is 9.61% for residential buildings with an elevator. It is a little higher than for the walk-up apartments with a ground floor premium of 8.54%. The results reveal that the influence of the type and total number of floors of residential buildings on the ground floor premium is not as high as expected.

Finally, regardless of whether the residential buildings have an elevator or are walk-up apartments, the ground floor premium increases when the housing price increases. The ground floor premiums for residential buildings with an elevator range from 7.30% to 11.85%. They are a little higher than those for the walk-up apartments where the premiums range from 6.25% to 9.69%.

In summary, the vertical price gradient of high-rise residential buildings is nonlinear. The vertical price gradient differs depending on whether the residential buildings have elevators, and the influence of floor level-related accessibility on the housing price is higher than that for amenities. Compared to other floors, the ground floor has a 10% premium that might be due to its accessibility and land use flexibility. The difference in terms of the ground floor premium for the different types of buildings is small. These findings can help builders provide better pricing for different floor levels, and real estate appraisers to provide more reasonable floor level price/rent adjustments.

Acknowledgment

We thank the Ministry of Science and Technology, Taiwan for the funding support (MOST 109-2410-H-305-054-MY3).

References

Ahlfeldt, G. M., and Wendland, N. (2013). How Polycentric is a Monocentric City? Centers, Spillovers and Hysteresis. *Journal of Economic Geography, 13*(1), 53-83. doi: https://doi.org/10.1093/jeg/lbs013

Alonso, W. (1964). *Location and Land Use: Toward a General Theory of Land Rent*. Cambridge, MA: Harvard University Press.

Alter, A., and Mahoney, E. M. (2021). Local House-price Vulnerability: Evidence from the U.S. and Canada. *Journal of Housing Economics, 54*, 101791. doi: https://doi.org/10.1016/j.jhe.2021.101791

Chau, K., Ma, V., and Ho, D. (2001). The Pricing of the ‘Luckiness’ in the Apartment Market. *Journal of Real Estate Literature, 9*(1), 29-40. doi: https://doi.org/10.1080/10835547.2001.12090095

Cliff, A. D., and Ord, J. K. (1973). *Spatial Autocorrelation.* London: Pion Limited.

Colwell, P. F., and Sirmans, C. F. (1978). Area, Time, Centrality and Value of Urban Land. *Land Economics, 54*(4), 514-519. doi: https://doi.org/10.2307/3146175

Conroy, S., Narwold, A., and Sandy, J. (2013). The Value of a Floor: Valuing Floor Level in High-Rise Condominiums in San Diego. *International Journal of Housing Markets and Analysis, 6*(2), 197-208. doi: https://doi.org/10.1108/IJHMA-01-2012-0003

Coulson, N. E., and Engle, R. F. (1987). Transportation Costs and the Rent Gradient. *Journal of Urban Economics*, 21(3), 287-297. doi: https://doi.org/10.1016/0094-1190(87)90003-9

Danton, J., and Himbert, A. (2018). Residential Vertical Rent Curves. *Journal of Urban Economics, 107*, 89-100. doi: https://doi.org/10.1016/j.jue.2018.08.002

DiPasquale, D., and Wheaton, W. C. (1996). *Urban Economics and Real Estate Markets*. Englewood Cliffs, NJ: Prentice Hall.

Dubin, R. A. (1998). Spatial Autocorrelation: A Primer. *Journal of Housing Economics, 7*(4), 304-327. doi: https://doi.org/10.1006/jhec.1998.0236

Dunse, N., and Jones, C. (1998). A Hedonic Price Model of Office Rents. *Journal of Property Valuation and Investment, 16*(3), 297-312. doi: https://doi.org/10.1108/14635789810221760

Feng, S.-T., Peng, C.-W., Yang, C.-H., and Chen, P.-W. (2021). Non-linear Relationships between House Size and Price. *International Journal of Strategic Property Management, 25*(3), 240-253. doi: https://doi.org/10.3846/ijspm.2021.14607

Gibbons, S., and Machin, S. (2005). Valuing Rail Access Using Transport Innovations. *Journal of Urban Economics, 57*(1), 148-169. doi: https://doi.org/10.1016/j.jue.2004.10.002

Helsley, R. W., and Strange, W. C. (2008). A Game-Theoretic Analysis of Skyscrapers. *Journal of Urban Economics, 64*(1), 49-64. doi: https://doi.org/10.1016/j.jue.2007.08.004

Kau, J. B., and Sirmans, C. F. (1979). Urban Land Value Functions and the Price Elasticity of Demand for Housing. *Journal of Urban Economics, 6*(1), 112-121. doi: https://doi.org/10.1016/0094-1190(79)90019-6

Liao, W.-C., and Wang, X. (2012). Hedonic House Prices and Spatial Quantile Regression. *Journal of Housing Economics, 21*(1), 16-27. doi: https://doi.org/10.1016/j.jhe.2011.11.001

Liao, W.-C., and Zhao, D. (2019). The Selection and Quantile Treatment Effects on the Economic Returns of Green Buildings. *Regional Science and Urban Economics, 74,* 38-48. doi: https://doi.org/10.1016/j.regsciurbeco.2018.11.002

Lin, C.-C., Chen, C.-L., and Twu, Y.-C. (2012). An Estimation of the Impact of Feng-Shui on Housing Prices in Taiwan: A Quantile Regression Application. *International Real Estate Review, 15*(3), 325-346. doi: https://doi.org/10.53383/100160

Lin, Y.-J., Chang, C.-O., and Chen, C.-L. (2014). Why Homebuyers Have a High Housing Affordability Problem: Quantile Regression Analysis. *Habitat International, 43*, 41-47. doi: https://doi.org/10.1016/j.habitatint.2014.01.013

Liu, C. H., Rosenthal, S. S. and Strange, W. C. (2018). The Vertical City: Rent Gradients, Spatial Structure, and Agglomeration Economies. *Journal of Urban Economics, 106*, 101-122. doi: https://doi.org/10.1016/j.jue.2018.04.001

Mak, S., Choy, L., and Ho, W. (2010). Quantile Regression Estimates of Hong Kong Real Estate Prices. *Urban Studies, 47*(11), 2461-2472. doi: https://doi.org/10.1177/0042098009359032

McMillen, D. P. (1996). One Hundred Fifty Years of Land Values in Chicago: A Nonparametric Approach. *Journal of Urban Economics, 40*(1), 100-124. doi: https://doi.org/10.1006/juec.1996.0025

Mills, E. S. (1967). An Aggregative Model of Resource Allocation in a Metropolitan Area. *The American Economic Review, 57*(2), 197-210. Available at: https://www.jstor.org/stable/1821621 (Accessed: January 21, 2022).

Mok, H. M. K., Chan, P. P. K., and Cho, Y. S. (1995). A Hedonic Price Model for Private Properties in Hong Kong. *Journal of Real Estate Finance and Economics, 10*(1), 37-48. doi: https://doi.org/10.1007/BF01099610

Muth, R. F. (1969). *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. Chicago: University of Chicago Press.

Nase, I., Van Assendelft, N., and Remøy, H. (2019). Rent Premiums and Vertical Sorting in Amsterdam's Multi-Tenant Office Buildings. *Journal of Real Estate Finance and Economics, 59*(3), 419-460. doi: https://doi.org/10.1007/s11146-018-9684-x

Ohkawara, T. (1985). Urban Residential Land Rent Function: An Alternative Muth-Mills Model. *Journal of Urban Economics, 18*(3), 338-349. doi: https://doi.org/10.1016/0094-1190(85)90007-5

Ong, S. E., Ho, K. H. D., and Lim, C. H. (2003). A Constant-Quality Price Index for Resale Public Housing Flats in Singapore. *Urban Studies, 40*(13), 2705-2729. doi: https://doi.org/10.1080/0042098032000146858

Osland, L. (2010). An Application of Spatial Econometrics in Relation to Hedonic House Price Modeling. *Journal of Real Estate Research*, *32*(3), 289–320. doi: https://doi.org/10.1080/10835547.2010.12091282

So, H. M., Tse, R. Y. C., and Ganesan, S. (1997). Estimating the Influence of Transport on House Prices: Evidence from Hong Kong. *Journal of Property Valuation and Investment, 15*(1), 40-47. doi: https://doi.org/10.1108/14635789710163793

Sun, H., Tu, Y., and Yu, S.-M. (2005). A Spatio-Temporal Autoregressive Model for Multi-Unit Residential Market Analysis. *Journal of Real Estate Finance and Economics, 31*(2), 155-187. doi: https://doi.org/10.1007/s11146-005-1370-0

Wen, H., Gui, Z., Zhang, L., and Hui, E. C. M. (2020). An Empirical Study of the Impact of Vehicular Traffic and Floor Level on Property Price. *Habitat International, 97*, 102132. doi: https://doi.org/10.1016/j.habitatint.2020.102132

Wong, S. K., Chau, K. W., Yau, Y., and Cheung, A. K. C. (2011). Property Price Gradients: The Vertical Dimension. *Journal of Housing and the Built Environment, 26*(1), 33-45. doi: https://doi.org/10.1007/s10901-010-9203-8