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Comparison of Housing Price Elasticities Resulting from Different Types of Multimodal Rail Stations in Kaohsiung, Taiwan

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Constructing multimodal stations is one of the considered ways to implement transit-oriented development (TOD), with the goal of synergizing land use and transportation to promote both greater transit accessibility and sustainability in urban areas. Improvements in such accessibility have led to an uplift in land value and housing prices. These price changes have been primarily studied by analyzing the effects of proximity to stations of a single line or multi-line mass rapid transit (MRT) system. However, little attention has been paid to investigating the effects of different types of multimodal MRTs and railway joined stations. The aim of this study is to investigate the different types of multimodal stations in Kaohsiung City, Taiwan. We use publicly available housing transaction data to construct hedonic price models. The results show that in the Kaohsiung MRT stations, an increase of 100 m in distance from the stations results in a TWD 258,000[1] decrease in the average housing price. The housing price elasticity with respect to a 1% increase in distance from these stations is −0.067%.

Keywords

Transit-Oriented Development (TOD), Multimodal Station, Housing Prices, Kaohsiung MRT

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[1] USD 1 to TWD 33 in 2015

1. Introduction

Transit-oriented development (TOD) seeks to synergize land use and transportation to guide city development by providing various benefits — reduced transport costs and travel time, less traffic congestion, cleaner air, and more walkable neighborhoods. The land around TOD projects has been found to be more valuable, with uplifted neighboring housing prices resultant of closer proximity to transit stations (Bartholomew and Ewing, 2011, Duncan, 2011a, Zhang et al., 2018). The improved transportation accessibility provided by different types of transit stations has been shown to be a significant factor that positively influences housing prices both within and outside of TOD projects. The most common way of assessing how housing prices are affected by this accessibility is to include a proximity factor in the analysis (Higgins and Kanaroglou, 2016, Duncan, 2011a). Researchers have assessed the influences of commuter rail transit (CRT) (Bowes and Ihlanfeldt, 2001, Shi and Guo, 2009, Zhang et al., 2016), mass rapid transit (MRT) (Grass, 1992, Lin and Hwang, 2004), light rail transit (LRT) (Chen *et al*., 1998, Hess and Almeida, 2007, Duncan, 2011b, Yan et al., 2012), and bus rapid transit (BRT) (Dubé et al., 2018) stations on housing prices.

It has also been demonstrated that the increase in housing prices with improved access to multiple line stations is higher than for single line stations. The greater impact of multi-union modal stations on housing prices versus that of single-modal stations can be rationally predicted. The impacts of different types of transit services on land value, however, can be dissimilar among the transit modes and across each analysis (Cervero and Duncan, 2002). For example, Debrezion et al. (2007) conduct a meta-analysis and find that CRT stations have a higher positive impact on housing prices compared to LRT and heavy railway/MRT stations. In contrast, Higgins and Kanaroglou (2016) find significant differences in changes to land values across transit modes through a comparison of more than 130 analyses across 60 studies over a period of 40 years, and conclude that heavy rail transit and CRT lines have greater positive impacts on land value compared to LRT and BRT lines.

Additionally, little attention has been paid to the different types of multimodal stations in terms of the types of rail systems that are being joined. Uplifts in housing prices have been well documented by analyzing stations that correspond to one type of rail system or comparing stations that correspond to different types of rail systems, both within and across cities. Nonetheless, station construction guided by TOD policies could result in multimodal stations. These multimodal stations will serve as hubs for different types of rail systems, in order to facilitate higher connectivity among various transit rail services, thus providing passengers with a more convenient commute. It is therefore worth the effort to carry out a thorough study on this matter.

This study examines whether more different types of rail systems joined at MRT hub stations will bring about greater increases in housing prices. Our first hypothesis proposes that multimodal MRT stations have a greater impact on housing prices compared to single modal MRT stations. Our second hypothesis contends that multimodal MRT stations that consist of three types of rail systems have greater impacts on housing prices than double modal MRT stations.

2. Empirical Data and Methods

This study utilizes hedonic price function models to investigate the influence of proximity to transit stations on housing prices. Official housing transaction data in Kaohsiung are collected and processed by using ArcGIS. A regression model is then built to analyze the transaction data within 1 km to the MRT stations in Kaohsiung, followed by three regression models to investigate the different influence of three types of stations, namely single and double modal and multimodal MRT stations.

2.1 Data Collection and Processing

Kaohsiung provides a particularly rich setting for studying how housing prices are impacted by different types of multimodal stations. This city has four different modes of transit rail lines, including the Taiwan High Speed Rail (HSR), a CRT, an MRT, and an LRT[2], which is a trait not shared by other cities in Taiwan.

This study uses official housing data of transactions for houses, apartments, and condominiums in Kaohsiung from 2011 to 2015. The core data are obtained on a public website with real-estate information published by the Department of Land Administration, Ministry of the Interior, Taiwan. In total, 174,913 housing transaction data are obtained, as shown in Figure 1(a).

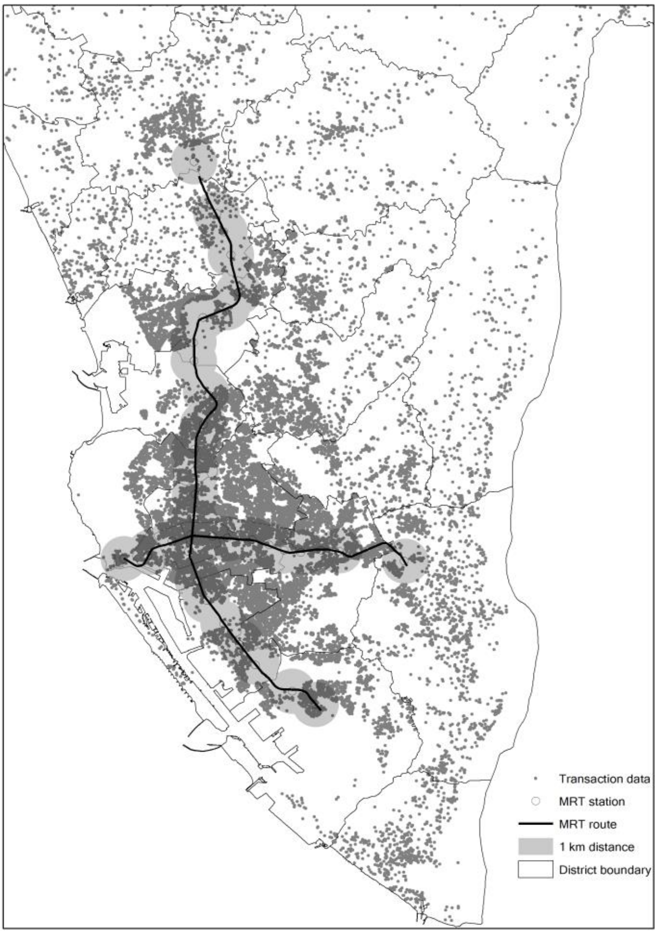
Based on the number of transit rail lines joined at a given MRT station, three types of representative MRT stations are examined here. Namely, the Judan[3], Kaohsiung and New Zuoying MRT Stations as shown in Figure 1(b). Not only do they have different number of lines, but these MRT stations also represent three different types of stations. The Judan MRT Station represents a single modal station which is for local MRT trips only. The Kaohsiung MRT Station represents a double modal union station, which has both an MRT and a CRT. The New Zuoying Station represents a multimodal union station, with an MRT

[2] The Kaohsiung LRT project is currently under construction, and only part of the line was open to ridership in 2016.
[3] The Judan MRT Station is also known as the Kaohsiung Arena Station.

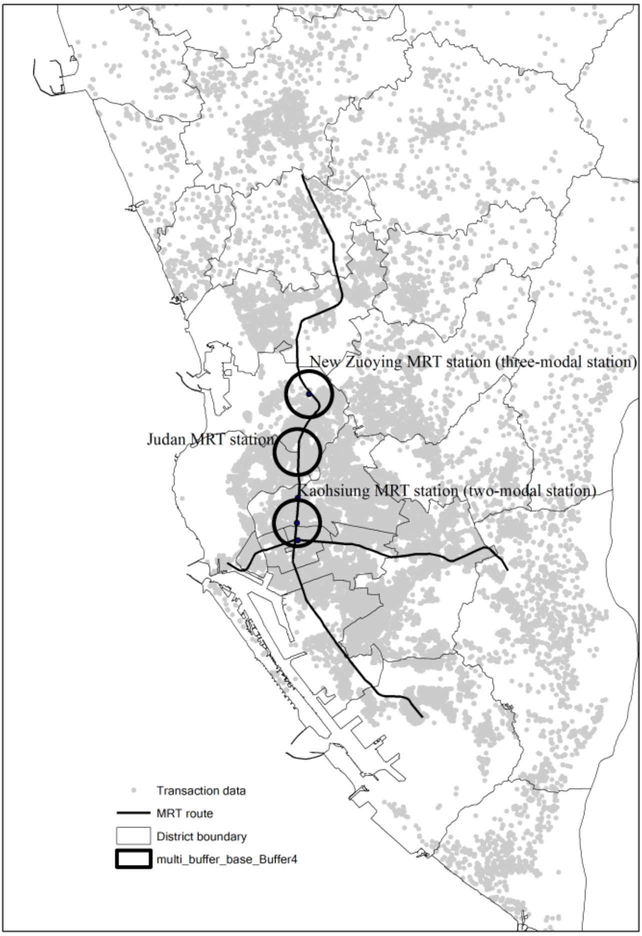
and HSR and a CRT, which is a hub station that connects travelers from the further regional areas to local transit. Only transaction data located within 1 km from these stations are used here because people are generally only willing to walk a maximum of 10 minutes to an MRT station (Dwess, 1975, Anas and Duann, 1985) and specifically, a maximum of 1 km in Taiwan (Chen, 2016, Lin and Hwang, 2003, Tai et al., 2011). Moreover, the majority of studies that have examined the impacts of MRT systems on housing prices in Taiwan have used distances from stations of less than 1 km (Peng et al., 2009).

Figure 1 Locations of Transaction Data in the 1 km Buffer Zones of the Three Kaohsiung MRT Stations Analyzed

(a) 1 km Distance from (Buffer Zone) All MRT Stations



(b) Three Representative Stations



The data are detailed records of these transactions, which include their price, site, and construction date, along with other attributes, including the property type, floor area, and floor level. This study uses geographic information system (GIS) tools to determine the transactions that took place within a 1 km radius to the closest MRT station, with 14,825 housing transactions out of 174,913 housing transactions that meet this criterion. Among the 14,825 transactions, 2,086 are within 1 km of Judan Station 1,231 of Kaohsiung Station, and 839 of the New Zuoying Station, as shown in Figure 1(b).

2.2 Descriptive Statistics

Within the 1 km distance from all of the MRT stations in Kaohsiung, the housing prices range widely from a minimum of TWD 10,000 to a maximum of TWD 1,044,133,000, with an average of TWD 7,859,500[4] (see Table 1). The average floor area is 151 m^2. Around 18% of the housing sold are terrace houses, and about 37% are located in the commercial zones. We have decided to include all of the sample cases without using statistical outlier screening, so that we can keep all of the detailed characteristics of the selected areas.

Due to fluctuations in the GDP, the data before 2015 are adjusted by using the consumer price index (CPI) and a GDP deflator, as shown in Table 2.

Table 1 Descriptive Statistics of the 14,825 Kaohsiung Housing Transactions within 1 km of All Municipal MRT Stations: 2011 to 2015

Vector	Variable		Code	Min.	Max.	Mean	Std.
Price	Housing price	(TWD 1,000)	PRC	10.00	1,044,133.	7,859.5	14,160.7
Structural	Floor area	(m^2)	HSAR	5.91	4,752.09	151.23	147.10
	Fourth floor	(1: yes)	STOR	0	1	0.08	0.28
	Building type (Terrace/no terrace)	(1: yes)	TYPE	0	1	0.18	0.38
Neighborhood	Commercial zone	(1: yes)	COM	0	1	0.37	0.48
Proximity	Distance to station	(meter)	ST_DIS	21.98	999.19	559.34	232.89

Note: Data obtained from the Ministry of the Interior, Taiwan. The exchange rate in 2015 was USD 1 to TWD 33.

Table 2 GDP Deflator in Taiwan (2015 as Base Year)

Year	2011	2012	2013	2014	2015
CPI	100	101.93	102.74	103.97	103.65
GDP deflator	1.036	1.016	1.008	0.996	1

***Note*:** Data obtained from the Directorate-General of Budget, Accounting and Statistics, Taiwan.

[4] USD 1 to TWD 33 in 2015.

2.3 Model Specifications

Empirical studies primarily use four types of models for housing price estimations, namely linear, double logarithmic, log-linear, and semi-logarithmic (Debrezion et al., 2007) models. All four types are used in this study. The general form of the linear regression model for estimating housing prices is given by:

$$(PRC)_i = \beta_0 + \sum_k \beta_k X_{ik} + \sum_k \alpha_k Z_{ik} + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma^2), \text{ i.i.d.} \tag{1}$$

The dependent variable $(PRC)_i$ is the estimated price of housing *i*. The independent variable X_{ik} represent housing structural characteristics (e.g., floor area, housing type, floor level) and neighborhood characteristics (e.g., land use, community amenities), while the independent variable Z_{ik} measures the proximity of the transit stations (i.e., distance to transit station). Our empirical models are constructed under the limitations of the variables available in the housing transaction data bank, as described above. The final models for each type of MRT station utilize five variables to explain for the housing prices (see Table 1) as given by:

$$(PRC)_i = \beta_0 + \beta_1 (HSAR)_i + \beta_2 (COM)_i + \beta_3 (STOR)_i + \beta_4 (TYPE)_i + \beta_5 (ST\_DIS)_i + \varepsilon_i \tag{2}$$

where the four vector X_{ik} variables include the housing floor area (*HSAR*), commercial zone location (*COM*) with a value of 1 when the transaction occurs in a commercial zone, housing type (*TYPE*) with a value of 1 for terrace houses, and floor level (*STOR*) with a value of 1 for transactions on the fourth floor. The word "fourth" shares the same pronunciation as "death" in the Taiwanese language, and represents an ominous feeling in the Chinese culture. Therefore, there is no inclination to buy housing on the fourth floor and this floor number only serves to reduce the housing price (Lin et al., 2012). The one vector Z_{ik} variable includes distance to the nearest station (*ST_DIS*). The variables *COM*, *STOR* and *TYPE* are dummy variables, therefore only *HSAR* and *ST_DIS* are adjusted to the double logarithmic specifications of the model represented by Equation (3). It is worth noting that the interpretation of the coefficients for $ln(HSAR)_i$ and $ln(ST\_DIS)_i$ is *housing price elasticity* with respect to the corresponding variables.

$$ln(PRC)_i = \beta_0 + \beta_1 ln(HSAR)_i + \beta_2 (COM)_i + \beta_3 (STOR)_i + \beta_4 (TYPE)_i + \beta_5 ln(ST\_DIS)_i + \varepsilon_i \tag{3}$$

3. Empirical Models

Prior to investigating the influence of the different multimodal stations with the three models, a Kaohsiung city model is built to fit the data within a 1 km distance by using all of the MRT stations in Kaohsiung. This is then followed with building models for the selected stations.

3.1 City Models for All MRT Stations in Kaohsiung

The correlations among the independent variables are first examined to confirm that there is no collinearity effect. Table 3 shows that the highest correlation among the five variables is less than 0.3, which suggests that all of these variables are not highly correlated.

Table 3 Results of the Correlation Analysis

	HSAR	COM	STOR	TYPE	ST_DIS
HSAR	1				
COM	.044	1			
STOR	−.050	−.030	1		
TYPE	.028	−.222	−.142	1	
ST_DIS	.003	−.243	.005	.090	1

Using all of the MRT stations in Kaohsiung, each independent variable in the four regression models has a high explanatory power at the 99% confidence level (see Table 4). This means that all of these independent variables can help to explain for the housing prices within a distance of 1 km from these stations. Among the four models, the double logarithmic model has the highest explanatory power with an R^2 of 0.718, followed by the linear, log-linear, and semi-logarithmic models.

The signs of the coefficients for HSAR, COM, and TYPE are all positive, thus suggesting that higher housing prices are related to larger floor areas, location in a commercial zone, and terrace houses. The coefficient sign for both STOR and ST_DIS is negative, thus suggesting that fourth floor transactions and greater distance to stations result in lower housing prices.

The linear model suggests that with an increase of 100 m in distance to a station, a TWD 258,000 decrease in average housing prices could be expected. In the double logarithmic model, when the distance is increased by 1%, the housing prices decrease by 0.067% at the 95% confidence level.

Table 4 Housing Price Models by Different Specifications

	Linear		Double logarithmic		Log-linear		Semi-logarithmic	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
Const.	-139.285	*** .000	0.586	*** .000	5.663	*** .000	−3865.11	*** .000
HSAR	6.646	*** .000	1.234	*** .000	.004	*** .000	1159.237	*** .000
COM	88.636	*** .000	.190	*** .000	.084	*** .000	217.382	*** .000
STOR	−92.533	** .002	−.194	*** .000	−.283	*** .000	−111.472	** .002
TYPE	221.926	*** .000	.285	*** .000	.368	*** .000	227.307	*** .000
ST_DIS	−.258	*** .000	−.067	*** .000	−.001	*** .000	−167.543	*** .000
Adjusted R^2	0.493		0.718		0.388		0.270	
Sample size	14,825		14,825		14,825		14,825	

Note: *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$

3.2 Models for Judan, Kaohsiung and New Zuoying Stations

To test the hypotheses proposed in this study, three representative stations are selected for their different modals. Recall that the Judan MRT Station (JU) has only one type of rail line (i.e., MRT), Kaohsiung MRT Station (KAO) is a hub for two different types of rail lines (i.e., CRT and MRT), and New Zuoying MRT Station (ZUO) for three different types of rail lines (i.e., HSR, CRT, and MRT). As the double logarithmic model has a higher explanatory power among the city models for all MRT stations in Kaohsiung, this model is used to test the hypotheses.

Table 5 Comparison of Type of Model of Selected Stations

Variable	New Zuoying MRT (ZUO)		Kaohsiung MRT (KAO)		Judan MRT (JU)	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
Const.	1.267	*** .000	1.387	*** .000	.631	*** .000
HSAR	1.181	*** .000	1.229	*** .000	1.255	*** .000
COM	.120	*** .000	.077	*** .000	.112	*** .000
STOR	−.029	.440	−.145	* .010	−.112	*** .000
TYPE	.466	*** .000	.545	*** .000	.178	*** .000
ST_DIS	−.123	** .004	−.182	*** .000	−.045	** .004
Adjusted R^2	0.770		0.798		0.757	
Sample size	839		1,231		2,086	

Note: $*p < 0.05$, $**p < 0.01$, and $***p < 0.001$

We initially hypothesized that the existence of more types of rail lines in a multimodal MRT station would have a greater influence on housing prices, and thus a higher housing price elasticity. Thus, the three following null hypotheses are proposed:

$$\beta^{ZUO}_{ST\_DIS} = \beta^{JU}_{ST\_DIS}, \beta^{KAO}_{ST\_DIS} = \beta^{JU}_{ST\_DIS}, \text{ and } \beta^{ZUO}_{ST\_DIS} = \beta^{KAO}_{ST\_DIS}.$$

The first two hypotheses are rejected due to *F*-values of 160.3 and 130.58, respectively, which correspond to a critical value of 3.84, with (1, ∞) degrees of freedom. We can statistically conclude that the housing price elasticity of the Judan MRT Station, with a value of −.045, is significantly different from the housing price elasticities of −.123 and −.182 of the New Zuoying and Kaohsiung MRT Stations, respectively. These findings indicate that multimodal MRT stations that serve as a hub for different types of railways, such as the New Zuoying and Kaohsiung MRT Stations, generally have greater impacts on housing prices compared with single-modal stations, such as the

Judan MRT Station. However, the elasticity coefficients of ST_DIS in the New Zuoying and the Kaohsiung MRT Station models show that the influence of the Kaohsiung MRT Station, as a double modal station, is larger yet not statistically different from that of the New Zuoying Station, a multimodal station. In this case, we cannot reject the null hypothesis of $\beta^{ZUO}_{ST\_DIS} = \beta^{KAO}_{ST\_DIS}$, which has an *F*-value of 3.25.

3.3 Sensitivity to Distance from Transit Station

A reduction in walking distance to the transit station from 1,000 m to 400 m, in intervals of 200 m, results in reduced R-squared values for the New Zuoying MRT Station model, whereas that of the Kaohsiung and Judan MRT Station models are slightly increased (see Table 6). In the New Zuoying MRT Station model, the housing price elasticity coefficients for distance to transit station are only significant for a distance of 1,000 m. In contrast, the elasticity coefficient for distance to transit station in the Kaohsiung MRT Station model only becomes insignificant at a distance of 400 m and that in the Judan MRT Station model remains significant when considering distances of 400 m, 600 m, 800 m, and 1,000 m from the station. These results suggest that stations with local or intra-city transportation services (i.e., MRT and/or CRT) could have a more lasting effect, albeit moderate, on housing prices in their neighborhoods. On the other hand, although the HSR as a regional transit mode that serves commuters in remote areas could have a stronger effect (i.e., larger elasticity coefficient) on uplifting housing prices, this effect might not be evident until there is a certain minimum distance (i.e., 1,000 m in our study) from the transit station. This phenomenon could be explained by the fact that people choose to live within walking distance to an MRT and/or CRT station to meet their daily local commuting needs. As for the HSR, people might be willing to live comparatively farther away from the station, since regional transits are less related to their day-to-day activities.

In summary, both the number of transit modes and their service types can add to the dynamics between multimodal stations and housing prices. Namely, the local transit modes would tend to have moderate yet lasting effects on housing prices at different walking distances from the transit stations, while regional transit modes would have larger impacts but only within a relatively specific distance from transit stations.

Table 6 Sensitivity Tests with Walking Distance to Transit Station: 400 m, 600 m, 800 m, and 1,000 m

Variable	New Zuoying MRT (ZUO)		Kaohsiung MRT (KAO)		Judan MRT (JU)	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
1,000 m						
Const.	1.267	*** .000	1.387	*** .000	.631	*** .000
HSAR	1.181	*** .000	1.229	*** .000	1.255	*** .000
COM	.120	*** .000	.077	*** .000	.112	*** .000
STOR	−.029	.440	−.145	* .010	−.112	*** .000
TYPE	.466	*** .000	.545	*** .000	.178	*** .000
ST_DIS	−.123	** .004	−.182	*** .000	−.045	** .004
Adjusted R^2	0.770		0.798		0.757	
Sample size	839		1,231		2,086	
800 m						
Const.	−.163	.798	1.251	*** .000	1.532	*** .000
HSAR	1.159	***.000	1.107	*** .000	1.191	*** .000
COM	.221	***.000	.019	.666	.082	*** .000
STOR	−.073	.249	−.204	*.011	−.130	*** .000
TYPE	.493	***.000	0.483	***.000	.477	*** .000
ST_DIS	.144	.160	−.068	**.010	−.116	*** .000
Adjusted R^2	0.683		0.800		0.787	
Sample size	515		761		1,652	
600 m						
Const.	1.134	.476	.106	.781	1.086	*** .000
HSAR	.756	.000	1.075	***.000	1.198	*** .000
COM	−.047	.710	.124	.033	.112	*** .000
STOR	−.168	.252	−.232	*.025	−.128	*** .000
TYPE	.790	.000	.430	***.000	.477	*** .000
ST_DIS	.246	.320	.129	*.031	−.048	** .005
Adjusted R^2	0.576		0.801		0.803	
Sample size	124		471		1248	
400 m						
Const.	(sample size too small)		−.372	.489	1.066	*** .000
HSAR			1.215	*** .000	1.182	*** .000
COM			.006	.947	.192	*** .000
STOR			−.120	.477	−.060	.168
TYPE			.298	.008	.303	.095
ST_DIS			.130	.167	−.044	.285
Adjusted R^2	-		0.860		0.790	
Sample size	14		165		632	

Note: $*p < 0.05$, $**p < 0.01$, and $***p < 0.001$

4. Suggestions for Further Studies

The impact of transit station proximity on housing prices has received wide attention in the TOD, transportation accessibility, and land economic literature. Most studies have investigated this impact by analyzing stations that only provide a certain mode of transit or by comparing stations among lines with each providing a different mode of transit. This study introduces a new factor, which is the number of different types of transit modes provided by a given station, to explore the corresponding differences in impacts on housing prices. This study confirms that multimodal transit stations have larger impacts on housing prices, based on higher housing price elasticities with respect to proximity.

However, the results show that the impact of multimodal MRT stations on housing prices is not greater than that of double modal MRT stations. One should note that the Kaohsiung MRT Station was built before and is located closer to the traditional center of the city of Kaohsiung than the New Zuoying MRT Station. Therefore, the influence of the former on the housing market might be inherently greater. These and related factors warrant a closer and wider range of spatial area investigation. It is also worth keeping in mind that should this be an empirical case study of a wider spatial area, examining the clustering of the standard errors due to housing price variations would be important to gain insights into the price variance.

In addition, this study finds that housing price fluctuations are significantly higher between 2010 and 2015, compared with the findings of Wu (2010), who uses data from 1997 to 1999 and shows an increase of TWD 38,000 with a decrease of 100 m in distance from the MRT stations. This indicates that further studies should take temporal factors into account.

Moreover, a bus transit hub is located near the Kaohsiung MRT Station, which is not considered in this study, as this hub is not located within the station. Nevertheless, further studies could attempt to include other transit services located near multimodal stations. Also, the COM dummy variable can only be used as a category explanation and has been criticized for failing to fully catch the variations of the zoning characteristics. It is strongly recommended that this variable is used to conduct a new simulation model under a control for zone fixed effects in future studies.

Lastly, the Taiwan HSR Station within the New Zuoying MRT Station provides regional transit instead of intra-city transit services, which could reduce the impact on local housing prices. Further studies could expand the research scope to include different cities that also have HSR systems to verify that inter-city transit rails have less impact on the local housing market. Different combinations of transit modes in multimodal stations can also be explored. For example, an MRT station combined with an LRT, or an HSR with an LRT, for a better understanding of their influence on housing prices.

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