Analysing Real Estate Prices in Singapore

Kevin Seow

Contents

Abstract

Property prices in Singapore have increased significantly in the last ten years, prompting ten rounds of property cooling measures by the government to stabilise the market. To make property investments in the current climate, a retail investor would have to make smarter, more informed decisions by understanding the market better. Using hedonic regression, spatial econometric methods and property price index construction, this paper explores possible investment opportunities to help the retail investor. The paper finds that proximity to train lines generally commanded a price premium, particularly for more established lines. In addition, the capitalisation of new train line development into property prices occurs mostly post announcement of the station locations. Meanwhile, investors should be wary of the allure of new (uncompleted) builds and proximity to popular schools, as they may not represent value in the property market. Based on the analysis, retail investors can also better estimate the price premium they should be willing to pay for desired property attributes.

Introduction

Asians, including Singaporeans, are said to have a "deep-seated desire to own property" (Shiao, 2018). In Singapore, this desire has manifested in rising property prices and ten rounds of property cooling measures[1] in the last ten years by the government, to stabilise the real estate market (Jiang, et al., 2015). Given the current climate, a retail investor looking to invest in Singaporean real-estate would have to exercise care, as the margins of gain have become thinner. One would have to understand the property market better, ascertain what property attributes are valued, to make more informed investments.

Using hedonic regression, spatial econometric methods and property price index construction, this paper analyses the Singapore private residential property market. It explores possible investment opportunities for the retail investor and guides them in pricing property attributes.

In particular, this paper will show that while proximity to train lines generally results in a property price premium, the premium differs by train line in favour of more established lines. In addition, property price premiums from the development of new train lines is mostly priced into property prices following the confirmation of station locations. Buyers should discount the allure of new (uncompleted) builds and of proximity to popular schools, as they may not represent value in the property market. This paper will also help retail investors better estimate the price premium for desired property attributes.

Understanding Singapore's Property Landscape

Singapore is an island state of 724 square kilometres (about half the size of London) with a population of 5.6 million[2]; it has a population density higher than that of Hong Kong. Its property market consists of both public and private housing. About 80% of Singaporeans live in public housing, which is heavily subsidised by the government and entails purchase and sale restrictions[3]. Private housing is market-based and built by private developers. Most private housing in land-scarce Singapore is high-rise non-landed, i.e. apartments and condominiums.

[1] Such measures include additional and increased stamp duties to be paid to purchase a second property, and tighter loan limits.
[2] Source: Singapore Department of Statistics.
[3] For example – locals are only allowed to own one public apartment; foreigners cannot buy public apartments.

Property developers typically start selling their properties four years prior to construction completion; these constitute new sales between the developer and buyer. There is also a liquid market for resales, from the property owner to a buyer (Fesselmeyer & Liu, 2014).

Due to land-scarcity and restrictions to curb traffic congestion, private vehicles are taxed heavily[4]. Therefore, public transport is an important mode for commuters. Singapore's public transport is underpinned by five Mass Rapid Transit (MRT) lines (see Appendix A for the train lines map). The East-West and North-South lines are the most established, having commenced operations since 1987. These lines were followed by the North-East line in 2003 and the Circle Line in 2009. The most recently completed line is the Downtown Line, which was opened in three phases, with the last phase opened in 2017.

Apart from proximity to train lines, property marketeers frequently advertise the proximity of properties to popular schools. Primary school admission is based on several criteria, one being the proximity of the home to school. Children who stay within 1km of the school are given priority over those who stay further away. Popular schools (which are perceived as top schools) are often oversubscribed. Therefore, it is not unheard of for families to move close to popular primary schools to increase enrolment chances.

Literature Review

The hedonic regression method is an established approach to model property prices, describing house prices as a function of a collection of attributes which are neither sold nor priced separately (Hill, 2011). This feature of the method allows one to estimate the value or "willingness to pay" of various attributes (de Haan & Diewert, 2013).

While commonly applied, the method can suffer from omitted variable bias, such as the omission of proximity to key amenities or differing household income distribution in the area (Sue & Wong, 2010). In addition, one has to take into account possible spatial autocorrelation when using the hedonic method as property prices tend to be spatially dependent (Basu & Thibodeau, 1998).

Notwithstanding these potential deficiencies, there is extensive literature employing the hedonic regression method to measure the effects of various attributes on property prices. One

[4] For example, a Nissan Qashqai that costs £20,000 to purchase in the UK retails for about £67,000 after taxes in Singapore.

such area would be on the impact of transport infrastructure on property prices. For example, Pan & Zhang employed a semi-logarithmic hedonic regression model to assess the impact of rail transit on property values in Shanghai. They estimated a premium of 152 yuan per square metre[5] for every 100 metres closer a property was to the train station (Pan & Zhang, 2008). However, in a similar study, Papon et al did not find any significant effects of the Paris T3 tramway line on nearby property prices (Papon, et al., 2015).

Others have observed that this proximity effect can differ by location, often as a result of other underlying factors, such as the distribution of socioeconomic strata in the area. Investigating property prices based on proximity to the bus rapid transit system in Columbia, Munoz-Raskin found that middle-income properties commanded a premium for proximity to the bus transit system. The opposite was observed for low-income and high-income properties. He suggested that the lower-income did not value the proximity because (i) they preferred to take cheaper paratransit (non-express) buses, and (ii) the bus rapid transit road corridor in low-income suburbs tended to be more polluted; meanwhile the high-income preferred private vehicular transport and regarded these corridors as noisy or less safe (Munoz-Raskin, 2010). In a similar vein, Tsai et al noted that land value gains from proximity to train stations in Brisbane were heterogeneous and dependent on local conditions (Tsai, et al., 2017).

The effects described thus far are cross-sectional, having been measured at a particular point in time. However, transport infrastructure development can influence property prices even prior to the commencement of operations, such as post-announcement and during construction. Bae et al analysed whether the development of a new subway line (Line 5) in Seoul affected the prices of nearby residential property. They observed that the distance to the new subway line only influenced property prices positively during the anticipatory years; the effect was not statistically significant when the line was running (Bae, et al., 2003). However, this study did not account for *general changes* in house prices (such as inflationary pressures) when comparing between years, calling into question the comparability of the effects across the years. This was possibly because the study was focused more on *whether* train line development influenced property prices, and less on the *magnitude* of influence.

A prior study in the US – on residential land values near the Southwest Side Rapid Transit Line connecting downtown Chicago to Midway Airport – also identified that anticipatory effects of the line development raised land valuations (McDonald & Osuji, 1995). However, this study did not look into the effects of the line after its completion, likely due to data

[5] Based on the average property priced at 13,828 yuan per square metre.

unavailability. A discount factor was used to account for difference in property prices across years.

In Singapore, Belcher & Chisholm, Deng et al, Sue & Wong have found that proximity to an MRT station contributes to higher property prices (Belcher & Chisholm, 2018; Deng, et al., 2012; Sue & Wong, 2010). Notably, these papers do not distinguish between the different MRT lines in Singapore, specifying only proximity to the closest MRT station. Diao et al looked specifically at the effect of the Circle Line MRT stations. They assessed that the opening of the stations increased prices of nearby properties by 8.6%, and detected anticipatory effects one year prior to operations (Diao, et al., 2017). However, they did not look into the differences in property prices before and post announcement of the station locations.

Apart from transport infrastructure, there has been significant research on whether proximity to good schools is capitalised into property prices. Feng & Lu estimated that every additional quality school per square kilometre increased home prices by 17.1% in Shanghai, while the new designation of a school as a quality school increased home prices by 6.9% (Feng & Lu, 2013). Jayantha & Lam and Fack & Grenet discovered similar effects in Hong Kong and Paris respectively, where quality schools were a positive amenity for properties and increased their prices (Jayantha & Lam, 2015; Fack & Grenet, 2010).

The picture is mixed in Singapore. Deng et al observed that private apartments within a 1km radius of popular schools suffered a discount, suggesting that the "negative effects of traffic congestion during school hours may outweigh the benefit of being close to popular schools" (Deng, et al., 2012). Sue & Wong found that public flats within a 1km radius of popular schools were a boon for resale value in one constituency but bane for another (Sue & Wong, 2010).

Apart from measuring the effects of attributes, the hedonic regression method is also used to develop property price indices to track price changes in the property market. Such indices can be used "to deflate nominal or monetary totals in order to arrive at estimates of underlying 'real magnitudes'" (Samuelson & Swamy, 1974). The Urban Redevelopment Authority (URA) - a Singapore government agency - publishes Singapore's property price indices (Urban Redevelopment Authority, 2015), with separate indices for public, private non-landed and private landed properties.

Methodology

Data

To investigate the effect of various attributes on property prices, property sales transaction data was obtained from URA's Real Estate Information System (REALIS). The data is based on property caveats – legal documents lodged by purchasers with the Singapore Land Authority to protect their interests in the property (Urban Redevelopment Authority, 2016). Transaction information includes the property price, price per square foot (psf), unit number (including floor level), floor area, postal code, postal district, tenure (Singapore's properties are freehold or 99 years leasehold), date of sale, including whether the property was completed at the time of transaction. Transaction records from 1 Jan 2006 to Jul 2019 were obtained. As the thrust of this paper is to identify potential investment opportunities, only private nonlanded property is analysed – public housing has purchase and sale restrictions that make them less conducive as investment instruments, while private landed property can generally only be purchased by Singaporeans.

The dataset recorded transactions involving en bloc (collective) sales to developers. These transactions had large floor area (see Appendix B for the distribution of transactions by floor area), and did not contain information such as floor level as all units were sold together. Not all en bloc sales were recorded, though they can be conservatively proxied as sales involving floor area of more than 2,000 square metres[6]. It is noted that the psf price is typically higher for such sales, as residents can get a better price selling collectively than individually. Given the lack of completeness and atypical nature of these sales, 348 such en bloc transactions were omitted, representing 0.1% of the dataset.

The latitude, longitude locations of residential apartments were obtained from the Singapore Land Authority's OneMap API service, as identified using their postal code. Every residential block in Singapore has a unique postcode. The dataset had 144,261 new sale and 145,289 resale transactions for 4,911 different residential blocks.

The locations of Mass Rapid Transit (MRT) stations were separately obtained from the Land Transport Authority's (LTA's) DataMall[7].

[6] The largest condominium unit in Singapore is 1,960 square metres (Kang, 2019).
[7] Light Rail Transit (LRT) stations were omitted from the analysis as they are feeder services, operating similarly to feeder bus services.

While there is no definitive listing of top schools, there are yearly media reports of popular schools with limited vacancies as well as awards issued by the Ministry of Education to schools which provide a holistic education with good management systems[8]. These sources were used to compile a list of popular schools. The location information of popular schools was also obtained from OneMap.

Distances between residential blocks and MRT stations, popular schools and the Central Business District (CBD) were calculated using GeoPy.

Models and index specification

Two models were developed to measure the effect of various attributes on property prices. The first model looks at property prices for all private non-landed properties in Singapore, providing an overall understanding of the property market, as well as the basis for the formulation of a property price index. The second model looks at property prices for properties within 500 metres of the Downtown Line, to ascertain when train line infrastructure is capitalised in property prices. In developing the second model, property prices are deflated using the property price index for comparability across years. Both models employ hedonic regression and are corrected for spatial autocorrelation.

Model 1: Overall Spatial Hedonic Model

A semi-log hedonic regression model was used for Singapore's private non-landed property market (Diewert, 2003):

$$\boldsymbol{Y}=\boldsymbol{X}\boldsymbol{\beta}+u$$

where Y is a vector of the natural logarithm of the prices psf of the properties, X is a matrix of observations on attributes (both locational and physical/structural) of the properties. β is the vector of attribute parameters to be estimated.

The time dummy variable method is popular in the literature, involving a pooled hedonic regression across the years with time dummy variables controlling for yearly effects. However, this method was eschewed for Model 1; it restricts other coefficients from taking on multiple values or changing over time (de Haan & Diewert, 2013). Instead, the characteristics prices approach as described by de Haan & Diewert was used: a separate regression was run for each

[8] The list was compiled from these sources (Ang, 2019; Ministry of Education, Singapore, 2019; Jaya, 2017)

year[9] in the dataset, allowing the attribute coefficients to vary from year to year. This facilitated the analysis of potential changes in attributes' impact over time.

For the locational variables, dummy variables captured whether an apartment was within 500 metres from an MRT station of each line. Based on behavioural and empirical studies, 400 to 500 metres is the conventional radius from a station that people are willing to walk (Pan & Zhang, 2008). A dummy variable was included for each MRT line, thereby distinguishing effects for different MRT lines. A variable recording the distance from the Central Business District was also incorporated. Postal districts in the form of dummy variables were included as they contain significant locational information [10] . Lastly, a dummy variable was incorporated for apartments located within one kilometre of a popular school, where the child would have priority admission.

In terms of the apartments' physical attributes, variables capturing the apartment size, age were used. A floor level variable was also included as an ordinal variable – Singaporeans prefer higher floors "to avoid bugs and to enjoy the breeze" (Fesselmeyer & Seah, 2018). Dummies accounting for the property tenure (freehold/99-year), as well as top and first floors were applied – apartments at these floors have a large proportion of outdoor space (Fesselmeyer & Seah, 2018), generally contributing to a lower psf price.

Accounting for spatial dependence

In applying hedonic regression for property prices, potential spatial autocorrelation has to be taken into account as property prices are often spatially dependent.

Lagrange Multiplier tests were conducted to determine the presence of spatial autocorrelation and select the most appropriate spatial econometric model (for more information on test interpretation and spatial model selection, see Anselin, 2005).

There are two main approaches for accounting for spatial effects: (i) the spatial lag model and (ii) the spatial error model (Kawamura & Mahajan, 2005). The spatial error model is used in this paper. It presumes the existence of omitted variable bias in the hedonic regression model "and that the omitted variable(s) vary spatially" (Kim, et al., 2003)[11]. As some locational attributes such as amenities are not captured, this model was opted for to remedy the

[9] Or partial year in the case of 2019 data.
[10] Singapore has 28 postal districts.
[1111] See also LeSage & Pace, 2009.

"potentially biasing influence of spatial autocorrelation, due to the use of spatial data" (Anselin, 2001). The spatial error model is:

$$\boldsymbol{Y}=\boldsymbol{X\beta}+u$$
$$u=\lambda \boldsymbol{W}u+\varepsilon$$

where λ is the spatial autoregressive coefficient, $\boldsymbol{W}$ is the spatial weight matrix, and ε is a random error term.

Constructing a Hedonic Double Imputation Fisher Property Price Index

Besides measuring the effects of attributes, the spatial hedonic regression of Model 1 was also used to estimate a property price index to track price changes in the property market. This index will later be used to deflate property prices in the subsequent spatial hedonic regression – Model 2 – that focuses on the Downtown Line development.

The Arithmetic Imputations approach as described by de Haan & Diewert is adopted to construct the property price index (de Haan & Diewert, 2013). To briefly explain the approach, consider an example where one wishes to compare changes between 2010 property prices and 2016 prices. One way to estimate this is by comparing 2016 to 2010 prices for the *same set* of properties sold in 2010. This would then require knowledge of 2016 prices for properties sold in 2010. However, "the [2016] prices of properties sold in [2010] cannot be observed and are "missing" because those properties, or at least the greater part, will not be resold in [2016]. Similarly, the [2010] prices of the properties sold in [2016] are unobservable" (de Haan & Diewert, 2013).

To address this, one can adopt the single imputation method where 2016 prices of the 2010 properties are estimated using the hedonic regression of Model 1, and imputed in the property price index calculations. This concept is extended and double imputation is used instead for our price index calculation in which *both* the 2016 and 2010 prices of the 2010 properties are estimated using the 2016 and 2010 hedonic regressions respectively. This can help to reduce the omitted variable bias (Hill, 2011).

Another aspect to address is the selection of index type: the Laspeyres, Paasche, or Fisher index amongst others. The Laspeyres index bases its calculations on the properties sold at period 0 (2010 in the example), while the Laspeyres index bases its calculations on those sold at period t (2016). The Fisher index is the geometric mean of the Laspeyres and Paasche index.

The Fisher index is employed here to mediate between the inflation overestimation tendencies of the Laspeyres index and underestimation of the Paasche index (Diewert, 2004).

For this paper, the property price index is calculated based on a fixed base year of 2006.

Model 2: Spatial Hedonic model for properties near Downtown Line stations

Model 1's spatial hedonic regression (discussed above) captures the property price premiums for each train line for each year in the dataset. However, what is less clearly captured is the point at which property prices are capitalised due to MRT line development. Model 2 focuses the analysis on properties near the Downtown Line, which was the only MRT line announced, constructed and opened for operation within the dataset timeline (2006-2019).

Stages 2 and 3 of the Downtown Line were announced on 27th April 2007, with the Ministry of Transport detailing station locations and line alignment (Stage 1 of the Downtown Line was announced earlier in 2005 and is therefore not included in this analysis (Feng, 2017).) Stage 2 of the Downtown Line then commenced operations on 27th Dec 2015, and Stage 3 on 21st Oct 2017 (Land Transport Authority, 2017).

The properties studied are limited to those within 500 metres of a Downtown Line station, to assess the effect of MRT line development on properties close to the stations[11]. For each of Stage 2 and Stage 3, separate regressions are run using similar attribute variables to Model 1[12], with the addition of dummy variables tracking three phases: (i) prior to announcement, (ii) following announcement and construction, (iii) after commencement of operation. Yearly time dummies were also included to track the yearly changes in the MRT line premium within each stage. Spatial autocorrelation was also corrected for, as per Model 1.

All property prices were rebased to 2006 prices using the calculated property price index, to account for general inflation in property prices.

[11] McDonald & Osuji provide justifications for a partial equilibrium model, looking only at properties close to station sites (McDonald & Osuji, 1995).

[12] The proximity to school and CBD distance variables were omitted. The findings of the proximity to school variable were inconclusive in Model 1 and thus omitted. Properties near the DTL stations in Phases 2 and 3 lay in a line parallel to the station, broadly coinciding with the Postal District dummies. To guard against multicollinearity, the CBD distance variables was removed.

Findings

Model 1 results: Overall Spatial Hedonic Regression Model

Table 1: Model 1: Average OLS and SEM summary 2010-2019

Summary (2010-2019)				
	OLS coefficient	No. of years p-value<0.05	SEM coefficient	No. of years p-value<0.05
(Intercept)	7.56	10	7.40	10
Floor Area (sqm)	-5.92E-04	10	-7.61E-04	10
Property Age	-0.01	10	-0.01	10
Freehold	0.12	10	0.11	10
Uncompleted Builds	0.10	10	0.10	10
Highest Floor	-0.09	10	-0.07	10
Lowest Floor	-0.03	10	-0.03	10
Floor Level	0.006	10	0.005	10
School within 1km	-0.03	10	-0.01	5
Distance to CBD (metres)	-3.41E-05	10	-1.75E-05	7
MRT - Circle Line	0.01	9	0.04	9
MRT - Downtown Line	0.02	6	0.02	9
MRT - East West Line	0.04	10	0.05	9
MRT - North East Line	0.02	8	0.04	7
MRT - North South Line	0.06	10	0.05	10
Adj R2 (OLS) / AIC (SEM)	0.81		-27670	

Table 1 shows the attributes' average coefficient and number of years the p-value was statistically significant in 2010-2019 for Model 1's hedonic regression (OLS) model and Spatial Error (SEM) model (see Appendix C for the full set of results). The adjusted R-square value for the OLS model is 0.81 on average, suggesting that about 80% of variation in property price psf is explained by the model. The Lagrange Multiplier Test indicated that there was spatial autocorrelation in the model, with the spatial error model preferred to the spatial lag model (see Appendix D for the Lagrange Multiplier Test results). The AIC was -27670 for the Spatial Error (SEM) model.

Figures 2a and 2b show the distribution of residuals' values before (the OLS model) and after (the SEM model) correcting for spatial autocorrelation. As exemplified by the green boxedareas, the residuals in the SEM model are less correlated than in the hedonic regression model.

Figure 2a: Residuals for OLS model

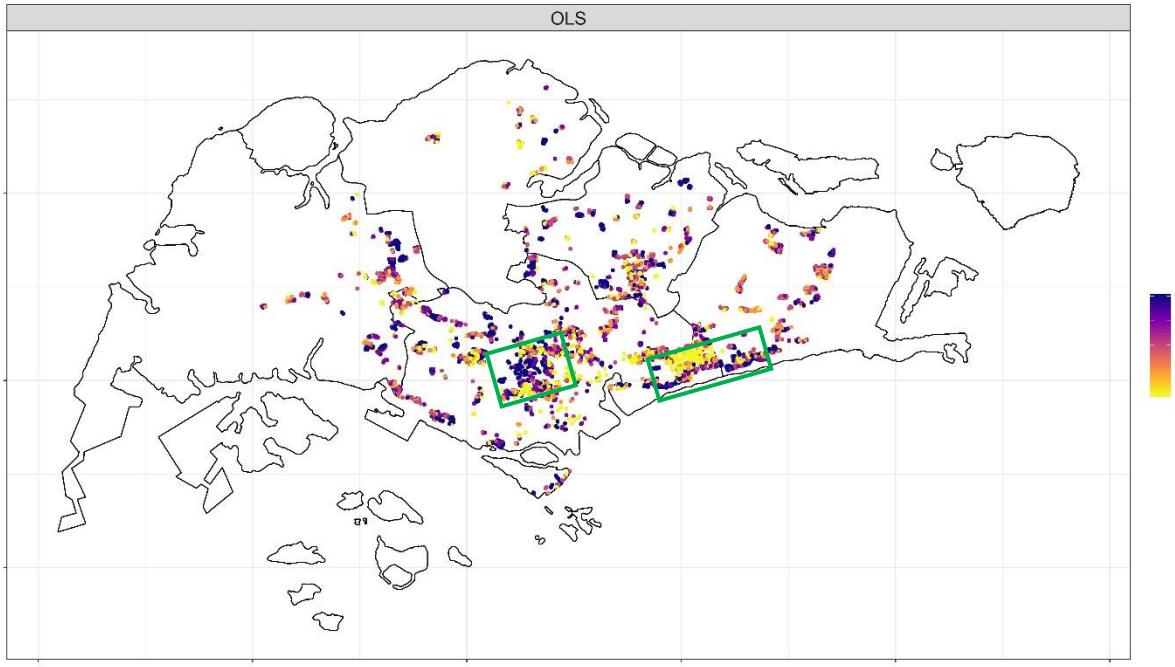
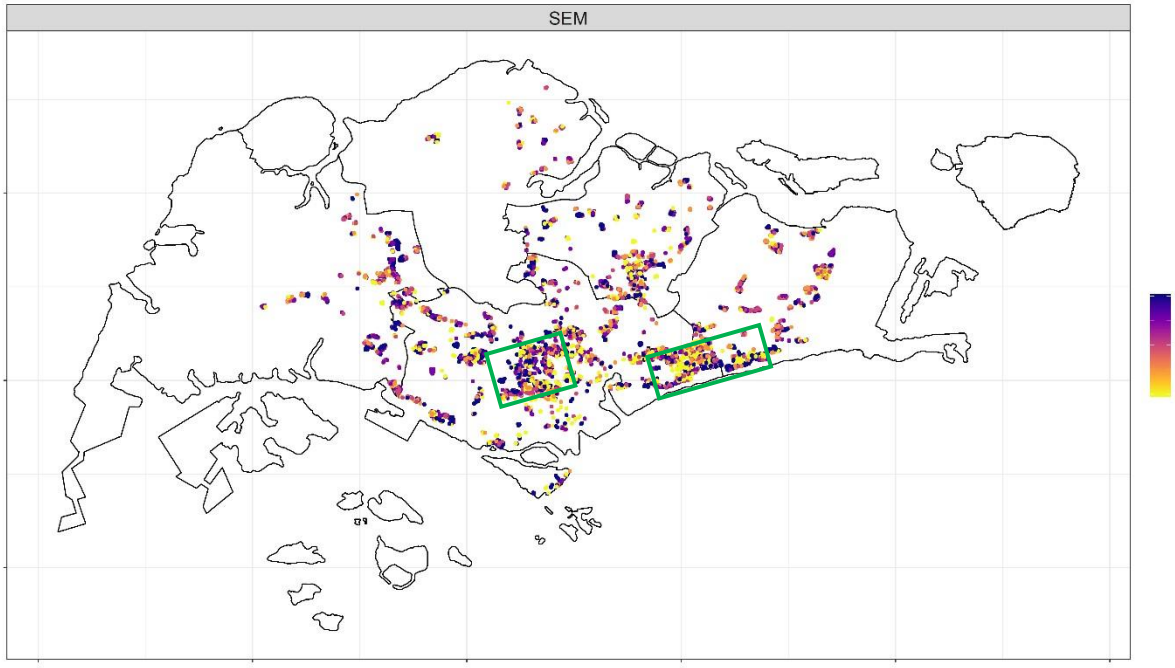


Figure 2b: Residuals for SEM model



While the attribute coefficient trends for both model types are broadly similar, all findings in this section are reported based on the SEM models.

Proximity to MRT train stations

Consistent with existing literature, properties within 500 metres of MRT lines enjoy a premium. However, this paper found that the premium is generally larger and more stable for

the more established lines, i.e. the North-South and East-West lines (5% on average for both lines). Premiums for the North East Line (NEL) were negative in 2006-2009. Reports contemporaneous to this period provide possible reasons why. The initial operations of the NEL were controversial as two stations – Buangkok and Woodleigh – were not opened when the line commenced operations in 2003. The operator had decided that "passenger usage of these two stations would be too low to justify the costs of running them", leading to residents complaining that the stations were "white elephants" (Low, 2005). They were only opened several years later[13]. In addition, local knowledge suggests that amenities (such as shopping malls, supermarkets, food centres) around NEL stations were less developed during this period[14], as the NEL extended towards the then-less-developed Northeast end of Singapore. The negative coefficients in 2006-2009 may therefore be capturing the lack of amenities/infrastructure near some NEL stations. This implies that it may have been beneficial to include other locational variables on amenities. In more recent years, a positive premium is observed from being near an NEL station, possibly as more amenities have sprung up around the stations.

Proximity to popular schools

The effect of proximity to popular schools appears mixed. The effect was statistically insignificant in 7 of the 14 years of the dataset. As Deng et al mentioned, the inconvenience of traffic congestion at peak periods may have outweighed the gains from priority registration (Deng, et al., 2012). At the same time, it is a very specific group who would prize being near a popular school i.e. parents who wish to send their *first* child to a popular school. Other criteria for Primary One admission, such as parents being alumni or siblings being existing students of these popular schools may be much more significant in determining school admission. This suggests that property agents marketing the premium of proximity to popular schools may be overselling this aspect to prospective buyers.

New (uncompleted) builds or completed apartments

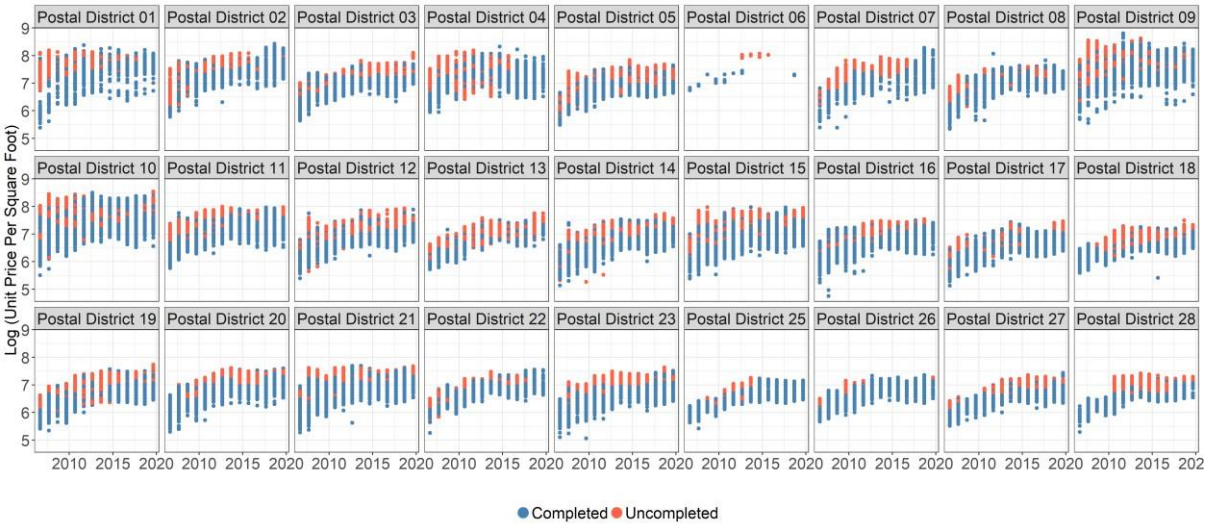
Uncompleted apartments receive a premium over completed apartments, costing on average 10% more than their completed counterparts. On the surface, this contradicts conventional wisdom where buyers are encouraged to buy new apartments under construction to sell when

[13] Buangkok and Woodleigh stations were only opened on 15 Jan 2006 and 20 Jun 2011 respectively.
[14] For example, a 600,000 sqft shopping mall, Nex, opened next to Serangoon MRT station in November 2010 (Goh, 2010) while a 381,000 sqft shopping mall, Waterway Point, opened next to Punggol MRT in January 2016 (Sofian, 2016).

completed, making a profit doing so. Further analysis suggests two effects – the "newness" effect and "development completion" effect.

The model captures the "newness" effect. After controlling for other attributes in the model, buyers still pay a premium for new uncompleted projects. Figure 3 shows the transaction prices psf for *freehold* apartments grouped by *postal district* over time, thereby controlling for the main *physical* and *locational* attributes respectively. The clustering of transactions for uncompleted projects (orange dots in Figure 3) indicate that, at the same point in time, one can typically expect to pay a higher price for uncompleted builds.

Figure 3: Distribution of prices psf for freehold apartments over time by postal district



The "development completion" effect refers to the conventional wisdom of buying uncompleted units and selling following completion. Indeed, 82% of residential projects had a lower mean price psf in the 3 years leading up to construction completion than in the 3 years after completion[15][16]. This indicates the buyers could expect the "development completion" premium for 8 in 10 residential projects.

[15] Based on the median price per square foot, the corresponding proportion was 84%.
[16] This is based on residential projects completed between 2009 and 2016. New builds completed in the periods from Jan 2006 to Dec 2008 and from Jan 2016 to Jul 2019 were omitted in order to capture transactions for the 3-year periods prior to and after construction completion.

Figure 4: Schematic of analysis comparing new build with already-built properties

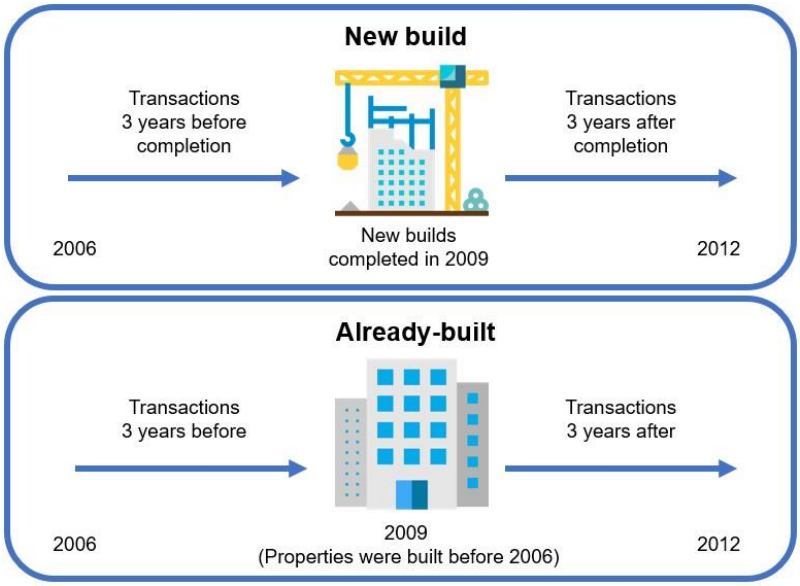
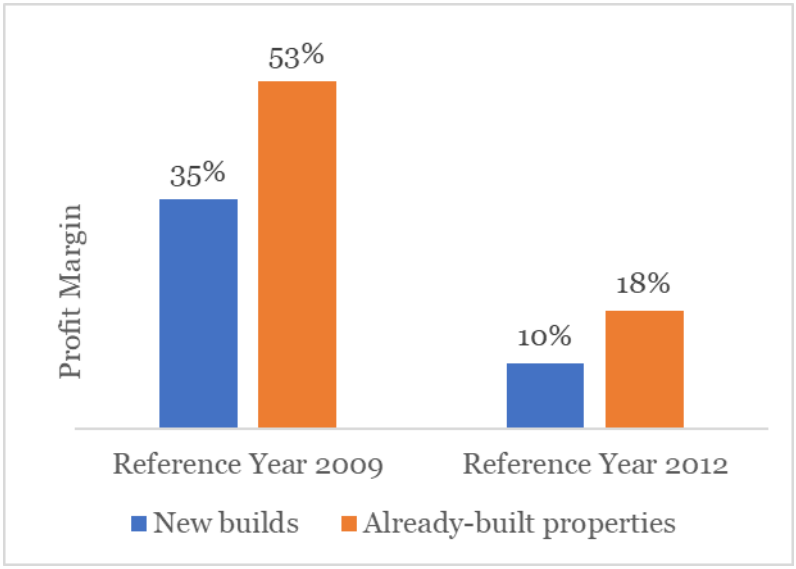


Figure 5: Profit margins for new build, already-built properties in reference years 2009 and 2012



However, purchasing new builds is unlikely to be the optimal use of an investor's resources. For properties that *completed construction* in 2009, the mean price psf in the three years after completion was 35% more than the mean price psf in the three years prior to completion[17]. In comparison, *already-built* properties[19] had an increase in mean price psf of 53% over the same period (see Figure 4 for visual representation of the analysis and Figure 5 for the findings as described). Repeating this analysis for properties completed in 2012 and comparing with

[17] The years 2009 and 2012 were chosen to ensure that there were sufficient transactions for analysis 3 years prior and after completion. [19] Completed before 2006.

already-built[18] properties, the former experienced a 10% increase while the latter a 18% increase. While it must be acknowledged that this analysis does not take into account aspects such as higher rental yield for new properties (a counter-point being that owners collect no rent while the property is being built), purchasing new builds appears suboptimal for investors.

Floor Area

In terms of the physical characteristics of properties, generally the larger the floor area, the more discounted the price psf. This is unsurprising, larger properties have higher transaction prices, which reduces the number of people who can afford them, hence reducing their price psf. Smaller apartments also tend to be easier to rent out; this effect is capitalised in their higher prices.

Other effects

The price premium for higher floors is consistently positive and highly significant. For each additional floor, one can expect to receive a 0.5% increase, though there are signs of a decreasing premium over time. On a $1 million property, this translates to $5,000 per additional floor. Properties on the top and ground floors command a lower price psf as they have less usable space. The discount is more pronounced for top floor units than ground floor units.

Freehold properties command a clear price premium, where freehold properties are on average 11% pricier. The age of property is also highly statistically significant – for every one year that a property is older, the price is discounted 1%, likely due to the degradation of physical infrastructure of the property.

[18] Completed before 2009.

Hedonic Double Imputation Fisher Property Price Index

Figure 6: Hedonic Double Imputation Fisher and URA property price indices

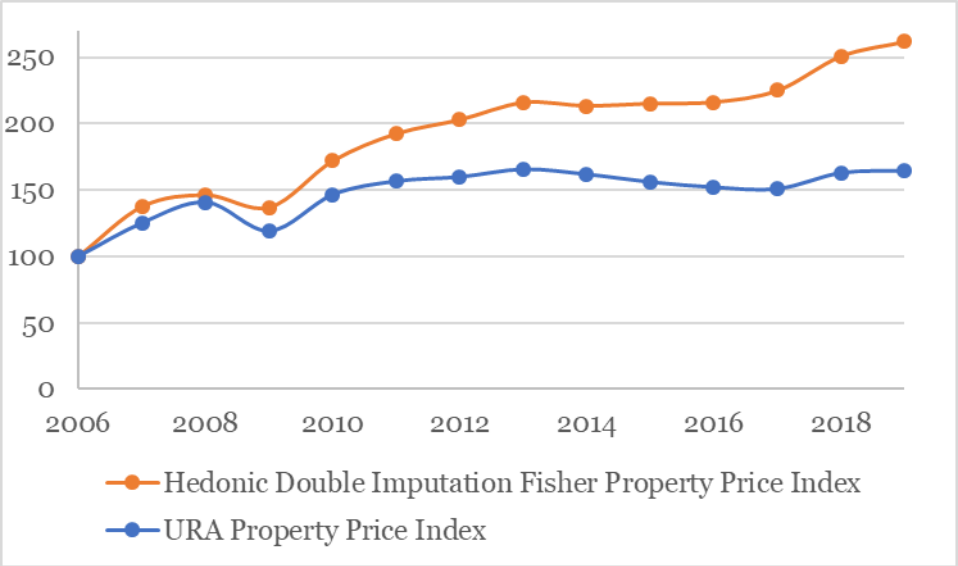


Figure 6 presents the calculated Fisher property price index based on the hedonic double imputation approach, with 2006 as the base year. The index suggests that private nonlanded property prices have increased significantly in Singapore in the last 13 years (20062019). While there was a dip in 2009 following the Great Financial Crisis, the rebound was strong and has generally been trending upwards since. The property price index by URA is also included, though the indices are not strictly comparable[19]. URA's index is weighted based on data from the last five quarters. URA also moved to the stratified hedonic regression approach only in 2014, adopting a stratification approach prior (see de Haan & Diewert, 2013 for information on the stratification approach).

Model 2 results: Downtown Line (DTL) effect over time

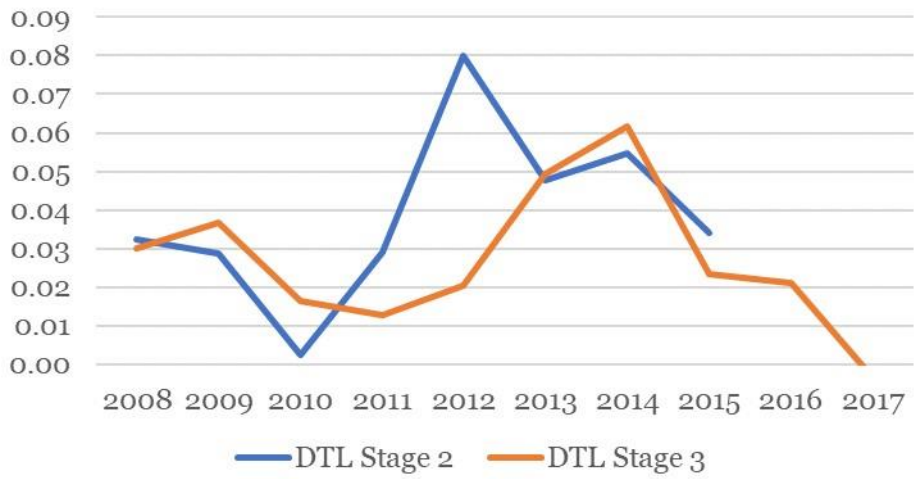
From Model 2, it can be observed that properties near the DTL stations saw real price increases from the line development. The model results for Stage 2 and Stage 3 are shown in Figure 7 (full results can be found in Appendix E). The capitalisation of DTL development into property prices mostly occurred following the announcement of station locations and during the construction phase, increasing by 28% for Stage 2 and 22% for Stage 3. A slight premium could be further gained following the line opening for Stage 3 but not for Stage 2.

[19] URA's index is reported quarterly. The quarters were averaged to yield a yearly index.

Figure 7: Model 2: Spatial Hedonic Model Results

SEM Results Summary - Downtown Line		
	Downtown Stage 2	**Downtown Stage 3**
(Intercept)	6.63	6.72
	(0.00)	(0.00)
Floor Area	3.89E-05	-4.85E-04
	(0.00)	(0.00)
Property Age	-0.021	-0.023
	(0.00)	(0.00)
Freehold	0.207	0.128
	(0.00)	(0.00)
Uncompleted Builds	0.135	-0.002
	(0.00)	(0.59)
Highest Floor	-0.075	-0.051
	(0.00)	(0.00)
Lowest Floor	-0.041	-0.070
	(0.00)	(0.00)
Floor Level	0.005	0.003
	(0.00)	(0.00)
Phase – Post-Announcement/Line Construction	0.244	0.197
	(0.00)	(0.00)
Phase - Line Open	0.241	0.237
	(0.00)	(0.00)

Figure 8: Price premium by years during the post-announcement phase



The post-announcement/construction phase was analysed by year to investigate if there remained opportunities during this phase to make an investment. Figure 8 shows the change in price premium by year during this phase compared with prior to the announcement in 2006[20]. The trend is inconclusive, though there may be a dip in the price premium three to four years after announcement. Therefore, the recommendation may be that if investors wish to take advantage of the slight premium to be gained following line opening, they should look to purchase the property several years following the announcement.

Conclusion

This paper analyses the Singapore property market from the point of view of a retail investor looking to make more informed property investments. The analysis provided several insights. Proximity to MRT lines generally commanded a price premium. This paper has added to the literature by ascertaining that the price premium differs for different lines, particularly for established MRT lines. Based on the analysis of properties near the Downtown Line, the capitalisation of MRT station proximity into property prices mostly occurs post announcement of the station locations. Meanwhile, investors can discount the utility of proximity near popular schools, and should also be wary of purchasing uncompleted properties – there are indications that they offer poorer returns on investment than completed properties. Investors can also quantitatively evaluate the premiums expected for property attributes, to better estimate the value of their purchases. For example, investors should not be willing to pay more than 10-15% for a freehold property compared to a 99-year tenure property with similar locational and physical attributes.

A limitation of the hedonic regression approach is that it suffers from omitted variable bias. It may be difficult to eliminate this bias totally (de Haan & Diewert, 2013). For example, renovations which may change the value of properties are unlikely to be easily captured. Nonetheless, the analysis can be strengthened by taking into account meaningful variables, such as proximity to other key amenities, as well as socioeconomic strata distribution.

[20] Taking into account both the price premium from the line construction period and price premium based on the year.

References

Anselin, L., 2001. Spatial econometrics. In: B. H. Baltagi, ed. *A Companion to Theoretical Econometrics*. Oxford: Basil Blackwell, p. 310–330.

Bae, C.-H. C., Jun, M.-J. & Park, H., 2003. The impact of Seoul's subway Line 5 on residential property values. *Transport Policy,* Volume 10, pp. 85-94.

Basu, S. & Thibodeau, T. G., 1998. Analysis of Spatial Autocorrelation in House Prices. *Journal of Real Estate Finance and Economics,* Volume 17, pp. 61-85.

Belcher, R. N. & Chisholm, R. A., 2018. Tropical Vegetation and Residential Property Value: A Hedonic Pricing Analysis in Singapore. *Ecological Economics,* Volume 149, pp. 149-159.

de Haan, J. & Diewert, E., 2013. 5. Hedonic Regression Methods. In: J. de Haan & E. Diewert, eds. *Handbook on Residential Property Prices Indices (RPPIs)*. Luxembourg: Publications Office of the European Union, pp. 49-64.

Deng, Y., McMillen, D. P. & Sing, T. F., 2012. Private residential price indices in Singapore: A matching approach. *Regional Science and Urban Economics,* 42(3), pp. 485-494.

Diewert, W., 2003. *1 Hedonic Regressions: A Review of Some Unresolved Issues*. s.l., s.n.

Diewert, W. E., 2004. Basic index number theory. In: P. Hill, ed. *Consumer price index manual: Theory and practice*. Geneva: ILO/IMF/OECD/UNECE/Eurostat/The World Bank, pp. 263-288.

Fack, G. & Grenet, J., 2010. When do better schools raise housing prices? Evidence from Paris public and private schools. *Journal of Public Economics,* Volume 94, p. 59–77.

Feng, H. & Lu, M., 2013. School quality and housing prices: Empirical evidence from a natural experiment in Shanghai, China. *Journal of Housing Economics,* 22(4), pp. 291-307.

Feng, Z., 2017. *Downtown Line: soaring to new heights*. Singapore: Straits Times Press.

Fesselmeyer, E. & Liu, H., 2014. Dynamic pricing in the Singapore condominium market. *Economic Letters,* 124(1), pp. 147-150.

Fesselmeyer, E. & Seah, K. Y. S., 2018. The effect of localized density on housing prices in Singapore. *Regional Science and Urban Economics,* Volume 68, pp. 304-315.

Hill, R., 2011. *Hedonic Price Indexes for Housing,* OECD Statistics Working Papers: OECD Publishing http://dx.doi.org/10.1787/5kghzxpt6g6f-en.

Jayantha, W. M. & Lam, S. O., 2015. Capitalization of secondary school education into property values: A case study in Hong Kong. *Habitat International,* Volume 50, pp. 12-22.

Jiang, L., Phillips, P. C. & Yu, J., 2015. New methodology for constructing real estate price indices applied to the Singapore residential market. *Journal of Banking & Finance ,* Volume 61, p. S121–S131.

Kang, V., 2019. *Living At The Top Of The World: The Biggest Condos In Singapore*. [Online] Available at: https://www.propertyguru.com.sg/property-managementnews/2019/7/181920/living-at-the-top-of-the-world-the-biggest-condos-in-singapore [Accessed 28 Aug 2019].

Kawamura, K. & Mahajan, S., 2005. Hedonic Analysis of Impacts of Traffic Volumes on Property Values. *Transportation Research Record,* 1924(1), pp. 69-75.

Kim, C. W., Phipps, T. T. & Anselin, L., 2003. Measuring the benefits of air quality improvement: a spatial hedonic approach. *Journal of Environmental Economics and Management ,* Volume 45, p. 24–39.

Knapp, G. J., Ding, C. & Hopkins, L. D., 2001. Do Plans Matter? The Effects of Light Rail Plans on Land Values in Station Areas. *Journal of Planning Education and Research,* 21(1), pp. 32-39.

Land Transport Authority, 2017. *Factsheet: Downtown Line 3 to open on 21 October 2017.* [Online]
Available at: https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=5c4e424c-1a46-44cb92d0-212e37a2b6df [Accessed 28 08 2019].

LeSage, J. & Pace, R. K., 2009. *Introduction to Spatial Econometrics.* Boca Raton: Chapman & Hall/CRC.

McDonald, J. F. & Osuji, C. I., 1995. The effect of anticipated transportation improvement on residential land values. *Regional Science and Urban Economics,* Volume 25, pp. 261-278.

Munoz-Raskin, R., 2010. Walking accessibility to bus rapid transit: Does it affect property values? The caseof Bogota, Colombia. *Transport Policy,* Volume 17, pp. 72-84.

National Library Board, 2013. *Mass Rapid Transit (MRT) system.* [Online]
Available at: http://eresources.nlb.gov.sg/infopedia/articles/SIP_2013-11-05_131443.html [Accessed 26 Aug 2019].

Pan, H. & Zhang, M., 2008. Rail Transit Impacts on Land Use: Evidence from Shanghai, China. *Transportation Research Record: Journal of the Transportation Research Board,* Issue 2048, p. 16–25.

Papon, F., Nguyen-Luong, D. & Boucq, E., 2015. Should any new light rail line provide real estate gains, or not? The case of the T3 line in Paris. *Research in Transportation Economics,* Volume 49, pp. 43-54.

Samuelson, P. A. & Swamy, S., 1974. Invariant Economic Index Numbers and Canonical Duality: Survey and Synthesis. *The American Economic Review,* 64(4), pp. 566-593.

Sharma, Y., 2013. *Asia's parents suffering 'education fever'.* [Online]
Available at: https://www.bbc.com/news/business-24537487 [Accessed 23 Aug 2019].

Shiao, V., 2018. *Singapore real estate will endure as popular asset class.* [Online]
Available at: https://www.businesstimes.com.sg/government-economy/singapore-realestate-will-endure-as-popular-asset-class [Accessed 28 Aug 2019].

Sue, E. D. & Wong, W.-K., 2010. The political economy of housing prices: Hedonic pricing with regression discontinuity. *Journal of Housing Economics,* 19(2), p. 133–144.

Tsai, C.-H. (., Mulley, C., Burke, M. & Yen, B., 2017. Exploring property value effects of ferry terminals: Evidence from Brisbane, Australia. *Journal of Transport and Land Use,* 10(1), pp. 119-137.

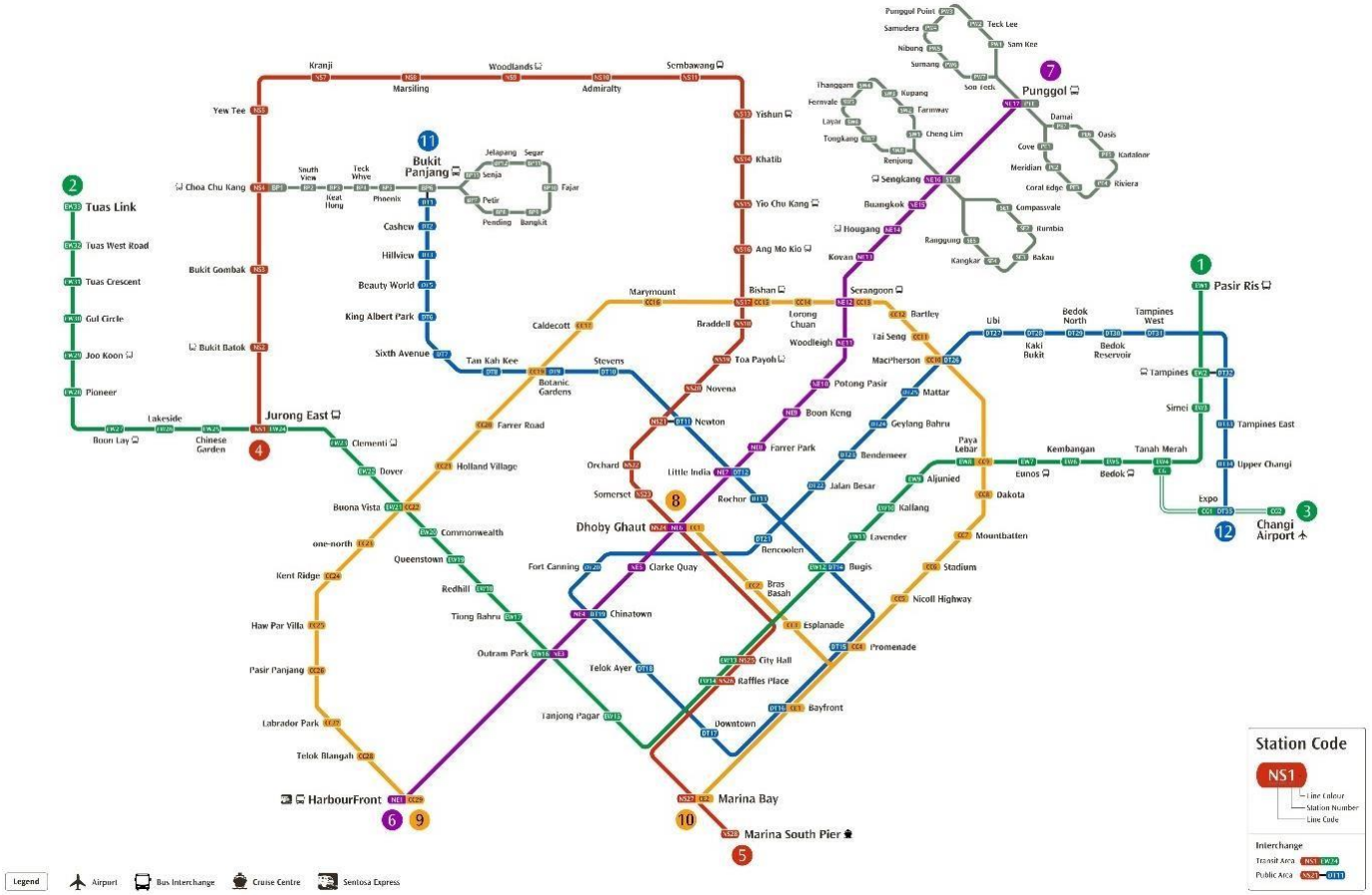
Urban Redevelopment Authority, 2015. *URA improves property price index (PPI) to better reflect price changes in private residential market.* [Online]
Available at: https://www.ura.gov.sg/Corporate/Media-Room/Media-Releases/pr15-16 [Accessed 24 Aug 2019].

Urban Redevelopment Authority, 2016. *Private Residential Property Transactions*. [Online] Available at: https://www.ura.gov.sg/realEstateIIWeb/transaction/search.action [Accessed 21 August 2019].

Appendices

Appendix A

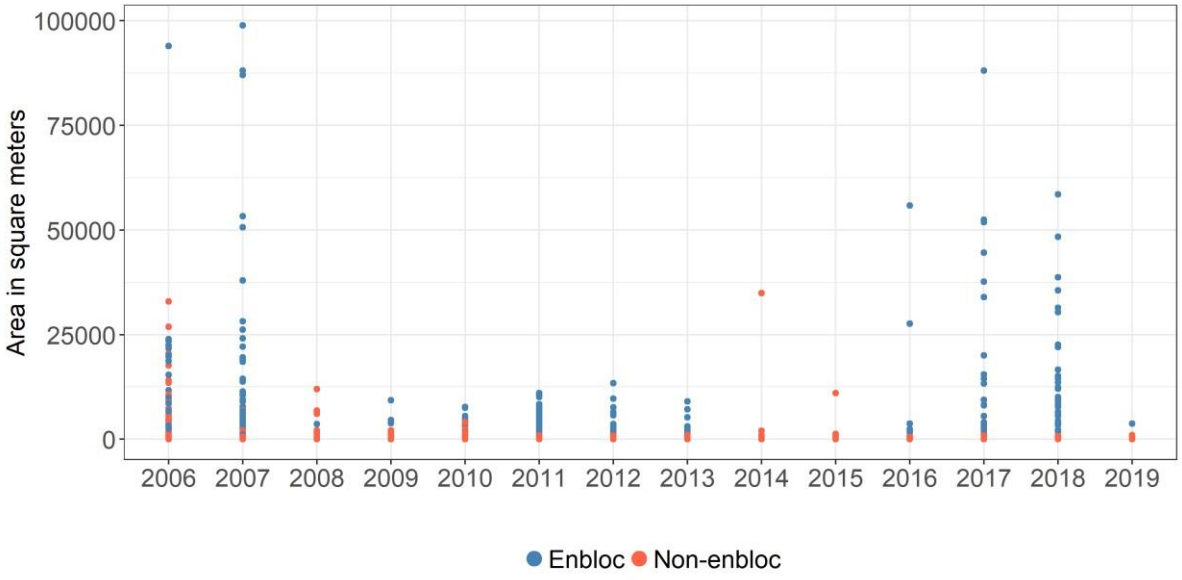
Figure A1: Map of Singapore's MRT and LRT lines



The East-West (green line in Figure A1) and North-South (red) MRT lines are the most established, having commenced operations since 1987. These lines were followed by the North-East (purple) line in 2003 and the Circle Line (yellow) in 2009. The most recently completed line is the Downtown Line (blue), which was opened in three phases, with the last phase opened in 2017. The MRT system is supported by three feeder Light Rail Transit (LRT) lines (grey), two in the Northeast and one in Northwest Singapore.

Appendix B

Distribution of transactions by floor area and year



Appendix C

Model 1: Hedonic Regression Results

OLS Regression Summary Results														
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
(Intercept)	6.87	7.05	7.27	7.36	7.47	7.52	7.43	7.58	7.54	7.49	7.58	7.56	7.75	7.69
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Areasqm	5.99E04	5.13E04	4.69E04	-7.65E05	-3.28E-04	-4.93E-04	-8.32E-04	-1.03E-03	-7.27E04	-5.63E04	-6.95E04	-6.52E04	-4.52E04	-1.46E04
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Property Age	-0.017	-0.011	-0.013	-0.013	-0.012	-0.013	-0.011	-0.010	-0.012	-0.013	-0.016	-0.016	-0.016	-0.015
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Freehold	0.160	0.132	0.067	0.094	0.104	0.099	0.132	0.143	0.108	0.119	0.101	0.107	0.109	0.128
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Uncompleted Builds	0.070	0.136	0.094	0.042	0.127	0.095	0.060	0.047	0.084	0.102	0.078	0.082	0.143	0.186
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Highest Floor	-0.191	-0.166	-0.124	-0.107	-0.087	-0.077	-0.091	-0.062	-0.078	-0.111	-0.098	-0.095	-0.092	-0.070
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Lowest Floor	-0.067	-0.044	-0.036	-0.051	-0.038	-0.024	-0.029	-0.042	-0.039	-0.020	-0.039	-0.029	-0.031	-0.027
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Floor Level	0.008	0.009	0.007	0.005	0.006	0.006	0.007	0.005	0.005	0.005	0.005	0.006	0.004	0.005
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
School within 1km	-0.038	-0.001	-0.034	-0.026	-0.045	-0.051	-0.025	-0.068	-0.015	-0.009	-0.050	-0.050	-0.008	-0.021
	(0.00)	(0.77)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.02)	(0.00)
Distance to CBD	-3.1E-05	-6E-05	-5E-05	-3.5E-05	-3.6E-05	-3E-05	-3E-05	-3.2E-05	-3.3E-05	-3.5E-05	-3.6E-05	-2.9E-05	-3.8E-05	-4.1E-05
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MRT - Circle Line	-0.036	0.034	0.056	0.044	0.071	0.012	0.050	0.002	0.003	-0.028	-0.033	0.029	0.024	0.010
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.54)	(0.62)	(0.00)	(0.00)	(0.00)	(0.00)	(0.17)
MRT - Downtown Line	-0.004	0.010	-0.037	-0.031	0.029	0.035	0.036	0.061	0.046	0.028	-0.005	-0.006	-0.006	0.010
	(0.47)	(0.07)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.24)	(0.14)	(0.22)	(0.17)
MRT - East West Line	-0.025	0.017	-0.010	0.031	0.020	0.046	0.088	0.059	0.025	0.028	0.030	0.036	0.066	0.039
	(0.00)	(0.00)	(0.23)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MRT - North East Line	-0.145	-0.143	-0.036	-0.082	-0.077	0.028	0.142	0.070	-0.048	0.003	0.001	-0.030	0.047	0.057
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.57)	(0.84)	(0.00)	(0.00)	(0.00)

MRT - North South Line	0.180 (0.00)	0.236 (0.00)	0.068 (0.00)	0.145 (0.00)	0.097 (0.00)	0.076 (0.00)	0.063 (0.00)	0.043 (0.00)	0.049 (0.00)	0.128 (0.00)	0.026 (0.00)	0.033 (0.00)	0.029 (0.00)	0.066 (0.00)
Postal District 02	-0.347 (0.00)	-0.139 (0.00)	-0.194 (0.00)	-0.247 (0.00)	-0.120 (0.00)	-0.126 (0.00)	0.006 (0.59)	-0.060 (0.00)	-0.008 (0.67)	0.038 (0.04)	-0.041 (0.04)	-0.015 (0.26)	-0.080 (0.00)	-0.185 (0.00)
Postal District 03	-0.447 (0.00)	-0.263 (0.00)	-0.297 (0.00)	-0.386 (0.00)	-0.329 (0.00)	-0.278 (0.00)	-0.148 (0.00)	-0.114 (0.00)	-0.097 (0.00)	-0.078 (0.00)	-0.139 (0.00)	-0.154 (0.00)	-0.269 (0.00)	-0.199 (0.00)
Postal District 04	0.107 (0.00)	0.363 (0.00)	0.214 (0.00)	-0.080 (0.00)	-0.131 (0.00)	-0.055 (0.00)	0.138 (0.00)	0.073 (0.00)	0.084 (0.00)	0.059 (0.00)	-0.038 (0.02)	0.049 (0.00)	-0.079 (0.00)	-0.052 (0.02)
Postal District 05	-0.436 (0.00)	-0.130 (0.00)	-0.240 (0.00)	-0.352 (0.00)	-0.308 (0.00)	-0.237 (0.00)	-0.048 (0.00)	-0.040 (0.02)	-0.062 (0.00)	-0.029 (0.05)	-0.057 (0.00)	-0.164 (0.00)	-0.208 (0.00)	-0.148 (0.00)
Postal District 06	0.077 (0.52)	-0.135 (0.34)	0.064 (0.73)	-0.191 (0.03)	-0.285 (0.00)	-0.191 (0.21)	0.392 (0.00)	0.588 (0.00)	0.654 (0.00)	0.597 (0.00)	NA (0.00)	NA (0.00)	-0.318 (0.00)	NA (0.00)
Postal District 07	-0.553 (0.00)	-0.368 (0.00)	-0.254 (0.00)	-0.313 (0.00)	-0.302 (0.00)	-0.222 (0.00)	-0.145 (0.00)	-0.111 (0.00)	-0.050 (0.00)	-0.035 (0.01)	-0.081 (0.00)	-0.080 (0.00)	-0.068 (0.00)	0.110 (0.00)
Postal District 08	-0.538 (0.00)	-0.416 (0.00)	-0.370 (0.00)	-0.474 (0.00)	-0.357 (0.00)	-0.340 (0.00)	-0.264 (0.00)	-0.297 (0.00)	-0.172 (0.00)	-0.179 (0.00)	-0.198 (0.00)	-0.226 (0.00)	-0.346 (0.00)	-0.317 (0.00)
Postal District 09	-0.032 (0.01)	0.117 (0.00)	0.004 (0.84)	-0.144 (0.00)	0.006 (0.52)	0.055 (0.00)	0.171 (0.00)	0.121 (0.00)	0.139 (0.00)	0.077 (0.00)	0.185 (0.00)	0.135 (0.00)	0.095 (0.00)	0.070 (0.00)
Postal District 10	0.011 (0.42)	0.305 (0.00)	0.176 (0.00)	-0.035 (0.00)	0.006 (0.60)	0.069 (0.00)	0.182 (0.00)	0.090 (0.00)	0.160 (0.00)	0.223 (0.00)	0.230 (0.00)	0.222 (0.00)	0.121 (0.00)	0.185 (0.00)
Postal District 11	-0.307 (0.00)	-0.190 (0.00)	-0.118 (0.00)	-0.254 (0.00)	-0.209 (0.00)	-0.115 (0.00)	0.017 (0.09)	-0.014 (0.37)	0.001 (0.91)	-0.017 (0.20)	0.014 (0.33)	0.047 (0.00)	-0.071 (0.00)	-0.081 (0.00)
Postal District 12	-0.714 (0.00)	-0.448 (0.00)	-0.476 (0.00)	-0.565 (0.00)	-0.520 (0.00)	-0.434 (0.00)	-0.283 (0.00)	-0.298 (0.00)	-0.221 (0.00)	-0.252 (0.00)	-0.257 (0.00)	-0.251 (0.00)	-0.341 (0.00)	-0.328 (0.00)
Postal District 13	-0.490 (0.00)	-0.413 (0.00)	-0.437 (0.00)	-0.500 (0.00)	-0.439 (0.00)	-0.414 (0.00)	-0.215 (0.00)	-0.208 (0.00)	-0.195 (0.00)	-0.175 (0.00)	-0.201 (0.00)	-0.187 (0.00)	-0.264 (0.00)	-0.246 (0.00)
Postal District 14	-0.667 (0.00)	-0.531 (0.00)	-0.510 (0.00)	-0.642 (0.00)	-0.539 (0.00)	-0.461 (0.00)	-0.311 (0.00)	-0.349 (0.00)	-0.311 (0.00)	-0.230 (0.00)	-0.274 (0.00)	-0.253 (0.00)	-0.321 (0.00)	-0.275 (0.00)
Postal District 15	-0.448 (0.00)	-0.140 (0.00)	-0.294 (0.00)	-0.406 (0.00)	-0.293 (0.00)	-0.242 (0.00)	-0.095 (0.00)	-0.109 (0.00)	-0.076 (0.00)	-0.051 (0.00)	-0.076 (0.00)	-0.034 (0.01)	-0.164 (0.00)	-0.077 (0.00)
Postal District 16	-0.356 (0.00)	-0.011 (0.51)	-0.150 (0.00)	-0.375 (0.00)	-0.297 (0.00)	-0.265 (0.00)	-0.075 (0.00)	-0.017 (0.29)	-0.046 (0.00)	0.001 (0.93)	-0.014 (0.38)	-0.094 (0.00)	-0.131 (0.00)	-0.051 (0.02)
Postal District 17	-0.433 (0.00)	-0.010 (0.67)	-0.147 (0.00)	-0.423 (0.00)	-0.381 (0.00)	-0.353 (0.00)	-0.191 (0.00)	-0.212 (0.00)	-0.098 (0.00)	-0.095 (0.00)	-0.121 (0.00)	-0.235 (0.00)	-0.229 (0.00)	-0.080 (0.00)
Postal District 18	-0.456 (0.00)	-0.046 (0.03)	-0.240 (0.00)	-0.476 (0.00)	-0.414 (0.00)	-0.377 (0.00)	-0.179 (0.00)	-0.213 (0.00)	-0.191 (0.00)	-0.121 (0.00)	-0.192 (0.00)	-0.263 (0.00)	-0.234 (0.00)	-0.177 (0.00)
Postal District 19	-0.491	-0.201	-0.362	-0.526	-0.431	-0.396	-0.244	-0.208	-0.126	-0.139	-0.124	-0.177	-0.266	-0.197

	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Postal District 20	-0.498	-0.203	-0.400	-0.456	-0.404	-0.275	-0.063	-0.065	-0.118	-0.079	-0.046	-0.053	-0.177	-0.094
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Postal District 21	-0.348	0.078	-0.036	-0.255	-0.154	-0.125	0.048	0.062	0.027	0.048	0.086	0.048	0.014	0.083
	(0.00)	(0.00)	(0.16)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.10)	(0.00)	(0.00)	(0.00)	(0.33)	(0.00)
Postal District 22	-0.324	0.080	-0.022	-0.392	-0.140	-0.196	-0.051	0.046	0.103	0.123	0.132	0.000	-0.040	0.063
	(0.00)	(0.00)	(0.48)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.99)	(0.03)	(0.03)
Postal District 23	-0.562	-0.115	-0.241	-0.492	-0.394	-0.311	-0.089	-0.097	-0.089	-0.064	-0.054	-0.102	-0.161	-0.089
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Postal District 25	-0.398	0.097	-0.135	-0.413	-0.340	-0.215	-0.062	-0.061	0.025	0.118	0.047	-0.075	-0.148	-0.018
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.32)	(0.00)	(0.05)	(0.00)	(0.00)	(0.58)
Postal District 26	-0.471	-0.094	-0.233	-0.345	-0.400	-0.335	-0.109	-0.133	-0.091	-0.067	-0.085	-0.106	-0.179	-0.120
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Postal District 27	-0.420	-0.036	-0.226	-0.461	-0.426	-0.374	-0.118	-0.105	-0.094	0.021	-0.061	-0.139	-0.197	-0.070
	(0.00)	(0.15)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.26)	(0.00)	(0.00)	(0.00)	(0.01)
Postal District 28	-0.579	-0.217	-0.352	-0.546	-0.255	-0.374	-0.068	-0.222	-0.214	-0.264	-0.245	-0.178	-0.236	-0.198
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adjusted R2	0.81	0.77	0.79	0.80	0.81	0.80	0.77	0.78	0.81	0.82	0.82	0.82	0.82	0.85

Model 1: Spatial Error Model Results

Spatial Error Model Summary Results														
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
(Intercept)	8.05	2.41	7.29	7.27	8.62	6.87	7.26	7.51	7.31	7.15	7.11	7.45	7.30	7.44
	(0.00)	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Areasqm	6.45E05	1.36E04	-1.65E04	-5.13E04	-5.94E04	-7.77E04	-9.89E04	-1.09E03	-9.06E04	-7.66E04	-8.59E04	-7.38E04	-6.12E04	-2.86E04
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Property Age	-0.017	-0.012	-0.013	-0.013	-0.012	-0.013	-0.012	-0.011	-0.013	-0.015	-0.017	-0.017	-0.016	-0.015
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Freehold	0.171	0.164	0.074	0.098	0.115	0.118	0.130	0.120	0.103	0.109	0.097	0.108	0.100	0.129
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Uncompleted Builds	0.056	0.135	0.114	0.054	0.142	0.100	0.073	0.067	0.074	0.099	0.078	0.068	0.126	0.150
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Highest Floor	-0.135	-0.130	-0.086	-0.088	-0.078	-0.065	-0.073	-0.055	-0.068	-0.097	-0.077	-0.074	-0.077	-0.049
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Lowest Floor	-0.048	-0.038	-0.033	-0.045	-0.035	-0.025	-0.033	-0.038	-0.028	-0.018	-0.043	-0.034	-0.028	-0.019

	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Floor Level	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.004	0.005	0.004	0.004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
School within 1km	0.002	0.048	0.012	0.007	0.008	-0.006	-0.031	-0.078	0.001	0.008	-0.025	-0.012	0.012	-0.003
	(0.74)	(0.00)	(0.18)	(0.17)	(0.08)	(0.18)	(0.00)	(0.00)	(0.89)	(0.21)	(0.00)	(0.02)	(0.01)	(0.76)
Distance to CBD	-3.4E-05	2.18E06	-7.3E-05	-3.2E-05	-2.5E-05	-1.8E-05	-1.9E-05	-4.2E-05	-1.6E-05	-4E-07	-1.8E-06	-1.3E-05	1.8E-06	-4.4E-05
	(0.00)	(0.73)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.93)	(0.69)	(0.00)	(0.65)	(0.00)
MRT - Circle Line	0.052	0.045	0.096	0.070	0.057	-0.010	0.063	0.046	0.029	0.008	0.017	0.055	0.051	0.092
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)	(0.17)	(0.00)	(0.00)	(0.00)	(0.00)
MRT - Downtown Line	-0.031	-0.036	-0.044	-0.056	0.007	0.022	0.008	0.044	0.071	0.034	0.028	0.020	-0.014	-0.056
	(0.00)	(0.00)	(0.00)	(0.00)	(0.11)	(0.00)	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
MRT - East West Line	-0.027	0.097	0.063	0.056	0.052	0.044	0.108	0.029	0.000	0.035	0.048	0.076	0.066	0.053
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.93)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MRT - North East Line	-0.147	-0.042	-0.013	-0.041	0.002	0.042	0.059	0.083	0.001	0.009	0.031	0.037	0.089	0.057
	(0.00)	(0.00)	(0.18)	(0.00)	(0.63)	(0.00)	(0.00)	(0.00)	(0.84)	(0.20)	(0.00)	(0.00)	(0.00)	(0.00)
MRT - North South Line	0.159	0.170	0.046	0.131	0.065	0.092	0.043	0.038	0.055	0.071	-0.022	0.020	0.042	0.076
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Postal District 02	-0.337	-0.381	-0.093	-0.119	-0.012	-0.099	0.035	0.134	0.101	0.052	-0.044	0.022	-0.041	-0.052
	(0.00)	(0.00)	(0.02)	(0.00)	(0.41)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.04)	(0.16)	(0.01)	(0.24)
Postal District 03	0.104	0.336	0.002	-0.002	0.185	0.095	0.089	-0.013	0.060	-0.107	-0.013	-0.141	0.028	0.297
	(0.02)	(0.00)	(0.97)	(0.96)	(0.00)	(0.01)	(0.00)	(0.72)	(0.24)	(0.01)	(0.76)	(0.00)	(0.77)	(0.00)
Postal District 04	-0.093	0.036	0.273	-0.024	0.020	-0.076	0.007	-0.114	-0.047	-0.219	-0.256	-0.418	-0.022	0.189
	(0.23)	(0.83)	(0.15)	(0.66)	(0.62)	(0.09)	(0.86)	(0.02)	(0.49)	(0.00)	(0.00)	(0.00)	(0.82)	(0.02)
Postal District 05	0.148	1.019	0.289	0.007	0.311	0.175	0.320	0.143	0.050	-0.139	-0.120	-0.017	0.202	0.154
	(0.11)	(0.00)	(0.03)	(0.95)	(0.00)	(0.21)	(0.03)	(0.02)	(0.63)	(0.06)	(0.26)	(0.81)	(0.09)	(0.19)
Postal District 06	0.365	0.080	0.052	-0.148	-0.005	0.045	0.700	0.933	0.916	0.691	NA	NA	-0.446	NA
	(0.00)	(0.51)	(0.74)	(0.08)	(0.94)	(0.72)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Postal District 07	0.076	0.337	0.012	-0.059	0.234	0.242	0.176	0.227	-0.241	-0.122	0.126	-0.045	0.052	0.149
	(0.13)	(0.00)	(0.84)	(0.20)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.02)	(0.39)	(0.59)	(0.08)
Postal District 08	0.107	0.282	0.108	-0.126	0.216	0.110	-0.091	-0.163	-0.235	-0.125	0.069	-0.163	-0.012	0.099
	(0.03)	(0.00)	(0.07)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.18)	(0.00)	(0.90)	(0.21)
Postal District 09	0.349	0.539	0.216	0.126	0.389	0.326	0.361	0.311	0.174	0.046	0.273	0.141	0.264	0.305
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.29)	(0.00)	(0.00)	(0.01)	(0.00)
Postal District 10	0.344	0.535	0.247	0.041	0.290	0.202	0.190	0.109	0.117	0.056	0.197	0.091	0.111	0.256

	(0.00)	(0.00)	(0.00)	(0.33)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.19)	(0.00)	(0.05)	(0.24)	(0.00)
Postal District 11	0.245	0.543	0.283	-0.010	0.319	0.230	0.077	-0.008	-0.027	-0.041	0.189	0.066	0.121	0.271
	(0.00)	(0.00)	(0.00)	(0.81)	(0.00)	(0.00)	(0.02)	(0.84)	(0.60)	(0.37)	(0.00)	(0.17)	(0.20)	(0.00)
Postal District 12	0.114	0.479	0.150	-0.167	0.182	0.022	-0.102	-0.069	-0.111	-0.147	0.029	-0.082	-0.003	0.123
	(0.03)	(0.00)	(0.01)	(0.00)	(0.00)	(0.58)	(0.00)	(0.09)	(0.04)	(0.00)	(0.57)	(0.10)	(0.98)	(0.12)
Postal District 13	0.331	0.359	0.297	-0.253	0.182	0.108	0.074	0.079	0.059	-0.043	0.110	-0.009	0.009	0.204
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.04)	(0.06)	(0.29)	(0.37)	(0.03)	(0.86)	(0.93)	(0.01)
Postal District 14	0.540	0.439	-0.160	-0.297	0.235	0.098	-0.008	0.025	-0.147	-0.013	0.045	-0.071	0.046	0.283
	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)	(0.15)	(0.84)	(0.60)	(0.02)	(0.82)	(0.53)	(0.21)	(0.64)	(0.00)
Postal District 15	0.594	0.600	-0.147	-0.178	0.250	0.137	0.084	-0.009	-0.157	-0.058	0.022	-0.155	-0.043	0.221
	(0.00)	(0.00)	(0.07)	(0.00)	(0.00)	(0.04)	(0.05)	(0.85)	(0.01)	(0.30)	(0.76)	(0.01)	(0.67)	(0.01)
Postal District 16	0.740	0.509	-0.065	-0.125	0.373	0.154	0.088	0.100	-0.103	-0.082	-0.084	-0.239	-0.034	0.263
	(0.00)	(0.00)	(0.46)	(0.03)	(0.00)	(0.03)	(0.05)	(0.06)	(0.12)	(0.20)	(0.27)	(0.00)	(0.74)	(0.01)
Postal District 17	0.607	0.239	-0.541	-0.622	0.272	0.062	-0.033	0.077	-0.059	-0.142	-0.242	-0.405	-0.287	0.039
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.39)	(0.51)	(0.19)	(0.43)	(0.06)	(0.00)	(0.00)	(0.01)	(0.70)
Postal District 18	0.708	0.512	-0.138	-0.279	0.337	0.089	0.007	0.027	-0.138	-0.077	-0.194	-0.365	-0.258	0.077
	(0.00)	(0.00)	(0.13)	(0.00)	(0.00)	(0.21)	(0.89)	(0.64)	(0.05)	(0.28)	(0.02)	(0.00)	(0.02)	(0.43)
Postal District 19	0.167	0.398	0.286	-0.203	0.339	0.205	-0.069	0.142	0.090	0.064	0.200	0.044	-0.055	0.170
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.11)	(0.00)	(0.12)	(0.20)	(0.00)	(0.40)	(0.58)	(0.05)
Postal District 20	0.159	0.469	0.300	-0.139	0.346	0.201	-0.019	0.087	-0.046	0.061	0.207	0.101	0.062	0.238
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.63)	(0.08)	(0.45)	(0.26)	(0.00)	(0.07)	(0.54)	(0.02)
Postal District 21	0.311	0.660	0.292	-0.008	0.253	0.178	0.184	0.062	0.059	-0.003	0.141	0.093	0.175	0.305
	(0.00)	(0.00)	(0.00)	(0.85)	(0.00)	(0.00)	(0.00)	(0.13)	(0.29)	(0.96)	(0.01)	(0.06)	(0.07)	(0.00)
Postal District 22	-0.241	10.521	0.894	-0.586	7.659	2.890	-0.040	-0.524	0.040	-0.022	0.017	-0.484	-0.247	0.531
	(0.97)	(0.20)	(0.13)	(0.05)	(0.10)	(0.61)	(0.94)	(0.00)	(0.79)	(0.83)	(0.95)	(0.55)	(0.73)	(0.00)
Postal District 23	0.234	0.744	0.233	-0.035	0.266	0.143	0.177	0.022	-0.003	-0.092	0.000	-0.026	0.066	0.221
	(0.00)	(0.00)	(0.00)	(0.45)	(0.00)	(0.00)	(0.00)	(0.62)	(0.96)	(0.07)	(1.00)	(0.61)	(0.51)	(0.01)
Postal District 25	0.075	4.534	0.290	-0.361	-1.692	3.254	-0.105	0.155	-0.049	-0.027	-0.017	-0.131	-0.433	0.309
	(1.00)	(0.80)	(0.77)	(0.58)	(0.87)	(0.61)	(0.78)	(0.78)	(0.90)	(0.98)	(0.98)	(0.93)	(0.71)	(0.43)
Postal District 26	0.261	0.558	0.403	-0.112	0.349	0.201	-0.066	0.159	0.002	0.111	0.198	0.062	-0.089	0.113
	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)	(0.00)	(0.18)	(0.02)	(0.98)	(0.06)	(0.00)	(0.31)	(0.41)	(0.29)
Postal District 27	5.031	-0.624	-0.075	-0.397	-2.697	0.958	0.032	0.139	-0.141	-0.303	-0.250	-0.296	-0.497	0.220
	(0.69)	(0.95)	(0.94)	(0.56)	(0.58)	(0.78)	(0.92)	(0.56)	(0.58)	(0.36)	(0.43)	(0.61)	(0.40)	(0.37)
Postal District 28	-3.410	4.995	-0.277	-0.221	-11.519	5.760	-0.716	-0.104	-0.032	0.114	0.276	0.197	0.063	0.197
	(0.84)	(0.79)	(0.83)	(0.82)	(0.11)	(0.30)	(0.20)	(0.73)	(0.63)	(0.06)	(0.00)	(0.02)	(0.68)	(0.12)
Lambda	0.999	0.999	0.986	0.985	0.999	0.999	0.988	0.974	0.962	0.990	0.985	0.992	0.989	0.956
AIC	-14895	-9345	-9516	-24838	-34657	-37270	-43293	-31427	-16386	-21596	-22831	-30884	-26569	-11789

Appendix D

Lagrange Multiplier Tests for Model 1

Lagrange Multiplier Tests for Spatial Model Selection - p-values														
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
LM - Error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LM - Lag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Robust LM - Error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Robust LM - Lag	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.26	0.42	0.13	0.00	0.00	0.61

Lagrange Multiplier Tests for Spatial Model Selection - Statistic Value														
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
LM - Error	131804	155272	25749	88330	298236	285789	238810	118792	11275	21644	45934	65427	35026	6410
LM - Lag	10444	13497	328	7160	12723	1867	9421	6895	87	118	675	2602	1316	36
Robust LM - Error	122199	143604	25433	81653	285924	283940	229471	111904	11190	21527	45262	62908	33720	6375
Robust LM - Lag	839	1829	12	484	412	18	82	7	1	1	2	83	10	0

Lagrange Multiplier Tests for Model 2

LM Tests for Spatial Model Selection - p-values		
	Downtown Phase 2	Downtown Phase 3
LM - Error	0.00	0.00
LM - Lag	0.00	0.00
Robust LM - Error	0.00	0.00
Robust LM - Lag	0.00	0.00

LM Tests for Spatial Model Selection - Statistic Value		
	Downtown Phase 2	Downtown Phase 3
LM - Error	76471	4134
LM - Lag	171	15
Robust LM - Error	76387	4137
Robust LM - Lag	87	19

Appendix E

SEM Results Summary - Downtown Line		
	Downtown Phase 2	Downtown Phase 3
(Intercept)	6.63 (0.00)	6.72 (0.00)
Floor Area	3.89E-05 (0.00)	-4.85E-04 (0.00)
Property Age	-0.021 (0.00)	-0.023 (0.00)
Freehold	0.207 (0.00)	0.128 (0.00)
Uncompleted Builds	0.135 (0.00)	-0.002 (0.59)
Highest Floor	-0.075 (0.00)	-0.051 (0.00)
Lowest Floor	-0.041 (0.00)	-0.070 (0.00)
Floor Level	0.005 (0.00)	0.003 (0.00)
Stage - Line Construction	0.244 (0.00)	0.197 (0.00)
Stage - Line Open	0.241 (0.00)	0.237 (0.00)
Year 2007	-0.181 (0.00)	-0.207 (0.00)
Year 2008	-0.212 (0.00)	-0.167 (0.00)
Year 2009	-0.216 (0.00)	-0.161 (0.00)
Year 2010	-0.242 (0.00)	-0.181 (0.00)
Year 2011	-0.215 (0.00)	-0.185 (0.00)
Year 2012	-0.164 (0.00)	-0.177 (0.00)
Year 2013	-0.197 (0.00)	-0.148 (0.00)
Year 2014	-0.190 (0.00)	-0.136 (0.00)
Year 2015	-0.210 (0.00)	-0.174 (0.00)
Year 2016	-0.225 (0.00)	-0.176 (0.00)
Year 2017	-0.201 (0.00)	-0.201 (0.00)
Year 2018	-0.207 (0.00)	-0.252 (0.00)
Year 2019	-0.242 (0.00)	-0.193 (0.00)
Postal District 10	0.050 (0.00)	NA NA
Postal District 11	0.066 (0.00)	NA NA

Postal District 14	NA NA	-0.466 (0.00)
Postal District 16	NA NA	-0.437 (0.00)
Postal District 21	-0.274 (0.00)	NA NA
Postal District 23	-0.476 (0.00)	NA NA
Postal District 03	NA NA	-0.006 (0.87)
Postal District 07	NA NA	0.017 (0.53)
Postal District 08	-1.323 (0.00)	-0.174 (0.00)
Postal District 09	0.073 (0.00)	0.158 (0.00)
Lambda AIC	0.846 -13780	0.684 -11138