SIZE ELASTICITY ON HOUSING RENT OF INFORMAL HOUSING MARKET – AN EMPIRICAL STUDY OF SUB-DIVIDED UNITS IN HONG KONG

KA MAN LEUNG*[1] and CHUNG YIM YIU[2]

[1]The University of Hong Kong, [2]The University of Auckland

ABSTRACT

In urban economics, tenants are commonly assumed to substitute between accessibility and housing size. The substitution would become more inelastic when the size decreases (Convexity of Size Elasticity). However, there is no empirical study on this hypothesis because minimum housing size is commonly regulated in formal housing. Informal housing, in which lower bound of housing size is non-existent, offer an opportunity for researchers to examine this hypothesis. Yet, differences between two markets render them non-comparable. This paper contributes by conducting empirical test on the convexity of size elasticity on rent by studying Hong Kong's sub-divided units (SDUs), which are subdivided in formal flats and the effect of proximity to public transportation on size elasticity. The results suggest that size elasticity on rent of smaller sized housing is lower. SDUs' size elasticity (with ¼ of the average whole flat size) is about half of the whole flats. The results also imply the lower bound of livable housing size. We further found that size elasticity on SDU rent decreases with the distance from metro station. SDU tenants are more willing to pay more for living closer to metro station, but less willing to pay more for larger housing size.

Keywords: Size Elasticity, Consumer Substitution Theory, Informal Housing, Sub-divided Units

Email contact: **u3004670@connect.hku.hk**

INTRODUCTION

Informal housing in urbanized cities has received considerable attention from scholars in recent years (Clough Marinaro, 2020; Gurran, Pill, & Maalsen, 2020), it is defined as an "accommodation provided beyond the formal regulations governing residential production and the housing market" (Gurran, Maalsen, & Shrestha, 2020). One of the major concerns of informal housing is on its small size and overcrowding (Nasreen & Ruming, 2019). However, most policies on informal housing have focused on the need for affordable decent housing and access to basic amenities, but "have missed the strong link between housing location-access to livelihood-affordable transportation options and activity patterns of low-income households" (Tiwari, 2016) (p.23). Moreover, the previous studies are mostly qualitative and there are very few empirical studies on the trade-off value of the housing size for the proximity to public transportation.

This paper is motivated by O'Sullivan's (2012) convex housing-price curve. According to consumer substitution theory, tenants would consume less floor area for higher proximity to the employment centers because the unit rent is higher (O'Sullivan, 2012), and it is normally assumed that the size elasticity of housing rent is not perfectly inelastic but decreases when the size decreases (Figure 1). However, there have not been any empirical tests on this hypothesis because the lower bound of housing size is normally regulated. In other words, we have not been able to observe the actual responsiveness of tenants in substituting between small housing size and high housing rent at city centres due to the regulations of minimum housing size in formal housing markets. Nowadays probably due to the ultra-high rents of housing at some global cities such as Hong Kong, micro-units or even nano-units are becoming more and more common, especially in the informal housing markets. It provides a natural experiment to test the consumer substitution effect at the lowest bound of housing size, i.e. the convexity of the size elasticity on rent.

[Figure 1 Here]

Even though there have been some studies on informal housing rents, the size effect on rents cannot be compared directly with that of the formal housing markets since two markets are in general highly different, no matter in qualities, facilities and environments. These housing differences would imply different household characteristics. Their size elasticities on rents measured by hedonic models are not directly comparable. In order to compare the size elasticities of housing units of formal and informal housing markets in a like-with-like comparison, this paper considers sub-divided units (SDUs) to control the differences between the housing attributes by comparing the rents of SDUs with that of the same whole flat. Besides, we further conduct a robustness test on the size elasticity on housing rent in the formal housing markets at one of the districts of the informal housing samples.

The merit of using SDUs is that they are subdivided from flats of formal housing. So, we can be sure that they are at the same locations, with the same structural qualities, neighborhoods and environment qualities, etc. In other words, the informal housing markets of Hong Kong provides a natural experiment for a like-with-like comparison of size elasticity of rents of housing units of different size types. In 2016, the median floor area of accommodation of SDUs was 10 square meters, which was25% that of all domestic households in Hong Kong (40 square meters) (Census and Statistics Department (C&SD), 2018b). This paper is therefore the first empirical study on the convexity of size elasticity on rents of extra-small-sized housing. In formal housing markets, minimum housing size is normally regulated. Chinese Society of Housing Studies (2008) reviewed the Minimum Housing Standards/Minimum Housing and Health Standards of Japan, Korea, Germany and the United States. For example, the minimum living space for one and two persons are about 13.94 square meters and 23 square meters in the United States; 25 square meters and 30 square meters in Japan. In the United Kingdom, the minimum floor area for any new home is 37 square meters (Institution of Civil Engineers, 2018).

In Hong Kong, the median per capita floor area of the SDUs was only 5.3 square meters (56.5 square feet), according to the Population By-census 2016 (C&SD, 2018b). The excessively small housing size of SDU makes it a good candidate for testing the convexity of size elasticity. SDUs are a hybrid type between formal and informal housing, which share some of the characteristics of the whole flats of formal housing while SDUs are mostly smaller in size and often have irregularities in building works. The convexity of size elasticity of informal housing and formal housing can therefore be studied, with other factors being equal. The arrangement of this paper is as follows: Section 2 reviews the relevant literature and identifies the research gap. Sections 3 and 4 elaborate the methodology and data. Section 5 reports the results and Section 6 concludes.

LITERATURE REVIEW

The urban concentration of the poor puzzles the urban economists since Alonso (1964) was published. Becker (1965) tried to explain the phenomenon by the income elasticity of demand for land and travel costs. However, more recently, Glaeser, Kahn and Rappaport (2008) found that "the primary reason for central city poverty is public transportation." (p.2) In other words, it is the proximity to efficient public transportation that causes housing rents increase and makes the poor to live in smaller sized housing units. Besides, Makarewicz, Dantzler, and Adkins (2020) suggested that transportation savings accruing to the lowest income households in urban areas are not sufficient to offset higher urban housing costs. Celhay and Gil (2020) also found that irregular settlements in Santiago offer a better connection to the geography of opportunities in the city and provide better neighborhood security than living in a subsidized housing unit. Compared to proximity to city centre, proximity to metro stations caused larger positive impact on unit price of informal houses (Zhang & Zhao, 2018). Glaeser and Kahn (2001) found a decentralized employment pattern in the American cities, which refuted the bid rent curve. Thus, we would incorporate the proximity-to-public-transportation factor instead of the distance from the CBD in the hedonic pricing model.

Glaeser et al. (2008) did not explore the housing conditions of the urban poor. If the urban concentration of poverty can be explained by the proximity to public transportation, there is a trade-off (or substitute) between commuting cost and rental expenditure. Owing to the convexity of the housing-price curve (O'Sullivan, 2012), i.e. the unit rent is increasing at an increasing rate when the housing unit is more proximate to public transportation. It means that poor households have to sacrifice non-housing expenditure or housing quality or both to live closer to public transportation. Leung, Yiu and Lai (2020) found that lower-income households in informal housing markets had higher rent-to-income ratio than the higher-income counterparts, and they paid a premium for the proximity to public subway transportation. It implies the impact on their residual income for other non-housing expenditure.

Housing Size Effect on Housing Prices

This paper studies the elasticity of housing size on rent for informal housing (SDU) in Hong Kong, as it provides a sufficiently small sized of housing sample which are subdivided within a normal structure of formal housing. Housing size (floor area) is commonly recognized to be one of the most important determinants of housing price (Chin & Chau, 2003). Almost all hedonic studies of housing prices would include housing size as one of the explanatory variables, but very few studies focused on the effect of size, let alone its convexity. Most of the studies found a statistically significant size effect on housing price or unit price (i.e. price per square feet or square meter), reflecting a strong relationship between size (S) and price (P). The size effect β'_s is commonly found to be positive on house price, or negative on unit price β_s. Mathematically, the magnitudes of the two estimates in a log-log hedonic pricing model are interchangeable by adding one to the size effect on unit price as shown in the following:

$$\ln(P/S) = \beta_s \ln(S) + \cdots$$

$$\ln(P) - \ln(S) = \beta_s \ln(S) + \cdots$$

$$\ln(P) = (\beta_s + 1)\ln(S) + \cdots$$

$$\ln(P) = \beta'_s \ln(S) + \cdots$$

However, there are far fewer hedonic studies on rent, probably because of the lack of rental data. The difference of the size effects on unit price and unit rent was not compared until Cui, Gu, Shen, and Feng (2018). They studied the effects of hedonic variables on housing prices and rent in Beijing and found that the marginal diminishing rate of size on the price (per square meter) (-0.2532) is less negative than that on the rent (per square meter) (-0.4774). The size elasticity of rent seems to be lower than that of housing price, yet explanations were not provided.

Housing Size Effect on Housing Rents

Rental market is a better place to observe the size elasticity since owning a house includes investment considerations. Besides, most of the households living in informal housing are low-income renters. Owing to liquidity constraints, low-income households are more likely to rent (Díaz McConnell, 2017; Engelhardt, 1996), and the poor rely more on public transportation (. Glaeser et al., 2008). They are also observed to choose living in proximity to city centres or public transportation hubs with higher unit rent. It is commonly observed that more rental listings are provided at city centres, which are normally smaller in size and of higher density. The concentration of Airbnb (short-term rentals) in small-sized apartments (Cheung & Yiu, 2020) also reflects the fact that short-term renters choose smaller sized flats rather than larger sized houses. This paper considers informal housing rental markets and puts forward a consumer substitution hypothesis that it is relatively easy for renters to substitute housing size for other characteristics such as transportation convenience when housing size is relatively large, but it is not the case for smaller sized units, thus a lower size elasticity on unit rent for smaller-sized housing units is expected. Most hedonic studies on housing rent commonly included size as one of the attributes, though their foci were not on size effect. Some analyzed apartment rent as apartment is becoming more common in large cities and the elasticity of size is generally low. From Benjamin and Sirmans (1994)'s detailed literature review, most of the studies found a significant size elasticity on rent. For example, Buchel and Hoesli (1995) found a size elasticity on apartment rent at 0.83 (-0.17 on unit rent) (calculated based on its semi-log result) and 0.91 (-0.09 on unit rent) for unsubsidized and subsidized apartments in Geneva. Rents are less responsive to size changes for unsubsidized housing. Scholars have examined various causes of size elasticity variations. Hoesli (1997) found a size elasticity of about 0.622 on rent (-0.378 on unit rent) in apartments in Bordeaux. Djurdjevic, Eugster, and Haase (2008) is a rare study that tested on the size elasticities of house rents at different municipalities of Switzerland. They found that the size elasticity of house rent (0.630 in the reference canton, i.e. -0.370 on unit rent) is positively associated with the average rental levels, i.e. "municipalities with higher average rents tend to have a greater rate of increase in rental prices associated with increases in dwelling area." (p.693). Their findings seem to suggest a linear relationship between log(rent) and log(area), and with different slopes for different municipalities. Yet they did not explain why. Löchl and Axhausen (2010) also found a similar magnitude (0.777) of size elasticity on asking rent in Zurich.

If the elasticity of rent is lower than that of housing price, the size elasticity for lower rent units are lower and the apartment rent has lower elasticity than the house rent (Hoesli, 1997), it is logical to hypothesize that informal housing would have a very low elasticity of size on rent as it is more difficult to adjust housing size when the size is very small. According to the consumer substitution theory, renters may choose to consume less housing floor areas for sparing on other consumptions. Unfortunately, there have been very few empirical studies on the size effect on rent of informal housing though small housing size is one of their major characteristics of informal housing markets. It is understandable as informal markets are commonly illegal in nature and rental data of informal housing is largely unavailable. In recent years, there have been some empirical studies on housing rents of informal housing markets. For example, Leung & Yiu (2019) studied SDU, which is a hybrid type of informal housing in Hong Kong because SDUs are subdivided within a legal structure and the whole flat is reworked into several smaller-sized units with or without toilet and pantry, and are commonly without government approvals (Liber Research Community, 2018). It is one of the most common types of informal housing in Hong

Kong. The authors conducted a hedonic regression test on the rent of SDUs and found a 0.02% to 0.03% increase in rent for one square foot increase in size. The size elasticity on rent is about 0.20 to 0.30. Yet, they did not compare it with the size elasticity of formal housing and did not test its non-linearity effect.Hui, Liang, and Yip (2018), on the other hand, found that the size effect on the unit rent of SDUs was -22.5% comparing with just -1.9% in the formal housing market. Huang (2017), however, found the opposite sign in the result. The author tested the size elasticity on the rent of SDUs and formal housing and found 8.4% increase in rent for 1% increase in size for formal housing, but –13.7% for SDUs. It does not make economic sense to have a negative size effect on total rent, but the author contended that "large size of SDUs leads to higher total price, probably beyond the expectation of those tenants, and results in a lower popularity." Since the previous results are confusing as shown in Table 1, this paper attempts to test and compare empirically the size elasticities of formal and informal housing rents.

[Table 1 Here]

Consumer Substitution Theory and Housing Price Curve

The reason for the poor to choose to rent a more expensive housing unit (in terms of unit rent per square meter) at the city centres has been questioned by many urban economists for decades. The classic Alonso-Muth-Mills (AMM) model (Alonso, 1964; Mills, 1967; Muth, 1969) contended that the rich would move to suburbs to own bigger houses for lower land prices while the poor households make trade-offs between proximity to jobs and housing prices. On the contrary, LeRoy and Sonstelie (1983) and Glaeser et al. (2008) posited that the poor choose to live closer to the public transportation node because they have a steeper bid-rent gradient. Adair, McGreal, Smyth, Cooper, and Ryley (2000) found that accessibility imposes important influence on housing prices in lower-income areas. Hu and Wang (2017) further found that places with higher job accessibility by public transit mode are more likely to attract poor households who do not own cars. Their results stress the importance of job accessibility for low-income households with limited transportation mobility but strong needs for access to jobs. However, very few of them examined how the poor households manage to live in the proximity to public transportation nodes. This paper fills the research gap by examining the trade-off between housing size and job accessibility for low-income households.

According to consumer substitution theory, tenants would consume less floor area for higher proximity to the employment centers (O'Sullivan, 2012), but there is little empirical evidence on this theory. Waxman, Liang, Li, Barwick, and Zhao (2020) found that people would spend less on other non-housing expenditure when housing prices increase. Marcus and Zuk (2017) suggested that households would make difficult tradeoffs, including tolerating crowding and poor housing conditions in order to secure housing in their preferred neighborhoods or school districts. This paper is an attempt to empirically test the responsiveness of the households' consumption of housing size in respect to rental level and proximity to public transportation.

METHODOLOGY

Convexity of Size Elasticity on Rent

We modify the theoretical model of Zabel (2004) by considering the residential location and size choices of low-income households. Assuming that a household i's utility U_i depends on housing services H_i, non-housing consumption C_i and a set of socio-economic and demographic characteristics z_i:

$$U_i = U(H_i, C_i, z_i) \quad (1)$$

It satisfies the household income y_i constraint:

$$y_i = C_i + r_H H_i \quad (2)$$

where r_H is the rent of a unit of housing service. We further assume that the income of low-income household equals to a fixed amount W_m which is close to the wage regulated by the Minimum Wage Ordinance ("Minimum Wage Ordinance, Cap. 608, Laws of Hong Kong," 2017). Low-income households are also found to spend about a fixed percentage ρ (about 30%) of their income on housing services (Leung et al., 2020).

$$\rho W_m = r_H H_i \quad (3)$$

Thus, it shows a convex relationship between r_H and H_i, with $\frac{dr_H}{dH_i} = -\rho W_m H^{-2} < 0; and\ \frac{d^2 r_H}{dH_i^2} = \rho W_m H^{-3} > 0.$

In other words, if the housing unit rent is high, it implies consumption of less housing services, such as cutting housing size, to make both ends of the housing and non-housing expenditures meet.

Hedonic Pricing Models

Rosen (1974) outlines the hedonic pricing approach that considers goods to be a vector of their utility-bearing attributes, categorized into structural, X, spatial, L and temporal, D characteristics. Equations (4a) and (5a), show respectively the hedonic pricing models in a log-log form on the rent of SDUs (subscript u) and on the rateable value of the whole-flat apartments without subdivision (subscript f):

$$\ln(r_{uits}) = c_u + \sum_{k=1}^{K} \gamma_{uk} \ln(X_{uki}) + \sum_{t=1}^{T} \alpha_{ut} D_{uit} + \sum_{s=1}^{S} \beta_{us} L_{uis} + \varepsilon_{uist} \ldots (4a)$$

$$\ln(r_{fits}) = c_f + \sum_{k=1}^{K} \gamma_{fk} \ln(X_{fki}) + \sum_{t=1}^{T} \alpha_{ft} D_{fit} + \sum_{s=1}^{S} \beta_{fs} L_{fis} + \varepsilon_{fist} \ldots (5a)$$

where r_{uits} and r_{fits} denote the monthly rent of the SDUs *ui* and the appraised rateable value of the whole-flat *fi* at time *t* at district *s* ($i = 1,\ldots,n$; $t = 1,\ldots T$; $s=1,\ldots S$). γ_k denotes the implicit price for the k^{th} property characteristic X_{jk} ($k = 1,\ldots, K$), D_{uit} and D_{fit} denote the time dummy variables, which is set to 1 if the ui^{th} or the fi^{th} property rented or appraised at time *t* and to 0 otherwise, L_{uis} and L_{fis} denote the district location dummy variables, which is set to 1 if the ui^{th} or the fi^{th} property rented or appraised at district *s* and to 0 otherwise, and ε_{uit} and ε_{fit} denote the error terms with mean zero and variance σ^2. The coefficients γ_k, β_j and α_t can be estimated by the Ordinary Least Squares Method.

The focus of this study is on the effects of two attributes, namely (a) housing floor area, A , and (b) proximity to public transportation, P , and their interactions, as shown in Models 1 to 4 - Equations (4b), (5b), (4c) and 5(c).

$$\ln(r_{uits}) = c_u + \gamma_{u1}\ln(A_{ui}) + \gamma_{u2}\ln(P_{ui}) + \sum_{k=3}^{K}\gamma_{uk}\ln(X_{uki}) + \sum_{t=1}^{T}\alpha_{ut}D_{uit} + \sum_{s=1}^{S}\beta_{us}L_{uis} + \varepsilon_{uist} \dots (4b)$$

$$\ln(r_{fits}) = c_f + \gamma_{f1}\ln(A_{fi}) + \gamma_{f2}\ln(P_{fi}) + \sum_{k=3}^{K}\gamma_{fk}\ln(X_{fki}) + \sum_{t=1}^{T}\alpha_{ft}D_{fit} + \sum_{s=1}^{S}\beta_{fs}L_{fis} + \varepsilon_{fist} \dots (5b)$$

$$\ln(r_{uits}) = c_u + \gamma_{u1}\ln(A_{ui}) + \gamma_{u2}\ln(P_{ui}) + \gamma_{u3}\ln(A_{ui}) * \ln(P_{ui}) + \sum_{k=4}^{K}\gamma_{uk}\ln(X_{uki}) + \sum_{t=1}^{T}\alpha_{ut}D_{uit} + \sum_{s=1}^{S}\beta_{us}L_{uis} + \varepsilon_{uist} \dots (4c)$$

$$\ln(r_{fits}) = c_f + \gamma_{f1}\ln(A_{fi}) + \gamma_{f2}\ln(P_{fi}) + \gamma_{f3}\ln(A_{fi}) * \ln(P_{fi}) + \sum_{k=4}^{K}\gamma_{fk}\ln(X_{fki}) + \sum_{t=1}^{T}\alpha_{ft}D_{fit} + \sum_{s=1}^{S}\beta_{fs}L_{fis} + \varepsilon_{fist} \dots (5c)$$

where γ_{u1} and γ_{f1} denote the implicit prices for the natural logarithm of the floor area (A_{ui} and A_{fi}) of the SDUs and the whole-flat apartments, i.e. the size elasticity on rent; γ_{u2} and γ_{f2} denote the implicit prices for the natural logarithm of the proximity to public transportation (P_{ui} and P_{fi}) of the SDUs and the whole-flat apartments, i.e. the accessibility effect on rent. γ_{u3} and γ_{f3} denote their interactive effects. Other structural attributes of the subject properties include building age, floor level, presence of independent toilet, presence of windows, existence of owners' corporation, and provision of professional property management services.

Rateable Value Comparison Method

It is well known that the hedonic pricing model is subject to omission bias. No matter it is comparing the size effects on price and rent or comparing subsidized to unsubsidized housing, or houses to apartments, it is almost impossible to identify all attributes of the housing units, especially the interior and the neighbourhood micro-qualities. For example, people may challenge that the above list of attributes does not include the school zones, which are often one of the most important criteria of housing location choice for households with children.

In order to compare accurately the size effects of formal and informal housing, we compare the market rent of the SDU with the appraised rent (rateable value) of the same flat. Since SDUs are subdivided from a flat, if we can compare the rents of the SDUs and those of the original flats, almost all other housing attributes can be controlled. The Rating and Valuation Department of the Government of Hong Kong Special Administrative Region regularly assesses the market rents of all properties in the city for the purpose of levying rates. The assessments are conducted by professional appraisers based on updated market information. This practice has a history of more than a century and the accuracy of the rateable values of properties are well recognized in the city.

Rateable value is an estimated annual rental value of a property at a designated valuation reference date, assuming that the property was then vacant and to let from year to year, on the basis that the tenant undertakes to pay all usual tenant's rates and taxes, whilst the landlord undertakes to pay the government rent, the costs of repairs and insurance and any other expenses necessary to maintain the tenement to a state to command that rent. The designated valuation reference date of the annual rateable value is October of the previous year (RVD, 2020b). SDUs are formed by subdividing a flat into two or more internally connected and externally accessible units commonly for rental purposes (C&SD, 2018b). Since SDUs are mostly not approved by the government, the Department would assess their market rents based on the original apartment flat conditions. Applying hedonic regression on the SDUs and the original apartment flats allows a like-with-like comparison of the size effects on rent, keeping other attributes constant. Figure 2 illustrates an example of subdividing a flat into two SDUs.

[Figure 2 Here]

The merit of using SDU for studying informal housing markets is its hybrid nature. Since all the SDUs are subdivided from an apartment flat in the formal housing markets, they share the same locational, structural and neighborhood characteristics of the original apartments in the formal housing markets. Better still, other non-subdivided apartments in the same districts provide market rental information of the districts. Thus, if we compare the market rents of the SDUs and the whole-flat apartments where the SDUs are subdivided from, we can eliminate the locational, structural and neighborhood effects in the hedonic pricing model, and avoid omission bias.

DATA

Table 2 shows the variable symbols and their descriptions. The subscript $x = u$ or $x = f$ to represent variables for the SDUs and the whole-flat respectively.

[Table 2 Here]

The physical features of informal settlements are generally not well documented (Jones, 2020). Besides, SDU household data are not publicly available. Thus, in this study, we collected first-hand SDU data with 200 samples from three years' surveys with the support of a team of social workers who provided services for SDU tenants. Data collection was carried out from 2017 to 2019. The SDUs are located in six District Council Districts, namely Kwai Tsing, Kowloon City, Kwun Tong, Sham Shui Po, Tsuen Wan as well as Central and Western Districts.

According to C&SD (2018b), 63.5% of the SDUs were located in the above six District Council Districts (out of 12 District Council Districts with SDU data). Among these Districts, the distribution of SDUs was as follows: Yau Tsim Mong District (22.0%) (1^{st} in the number of SDUs), Sham Shui Po District (15.8%) (2^{nd}), Kowloon City District (9.7%) (4^{th}), Tsuen Wan District (6.9%) (5^{th}), Kwun Tong District (5.4%) (7^{th}), Central and Western District (5.0%) (8^{th}). The study covered all District Council Districts in Kowloon except Wong Tai Sin District (its SDU number was not released in the government report (C&SD, 2018b)). The study areas also included Tsuen Wan and Kwai Tsing Districts, which were the top two districts with the most SDUs in the New Territories in 2016. (Table 3)

[Table 3 Here]

For Central and Western District, it had both large income inequality and high formal rent (C&SD & Centamap Company Limited, 2016). The income inequality in this District was the most serious among all districts in Hong Kong. The difference between upper quartile (HK$41,000) and lower quartile (HK$7,000) of monthly income from main employment of working population was HK$34,000. It was 2.2 times that of all Hong Kong households (HK$15,250) (C&SD & Centamap Company Limited, 2016). The median monthly rent of Central and Western District was HK$14,000 in 2016 which was 6.4 times that of all Hong Kong districts (HK$2,180). It ranked first together with Wan Chai District. The six districts covered in this study are close to urban center. The sampled SDUs are on average 840 meters from the nearest subway station, which is within walking distance.

To align with the designated valuation reference date of rateable value, the rental values of SDUs are adjusted to October of the previous year prior to data collection with reference to the rental indices of private domestic housing published by Rating and Valuation Department (Hong Kong Subdivided Flats Concerning Platform, 2018; RVD, 2020a). The average household size of the sample was 2.9 persons. It was similar to that of all Hong Kong domestic households (2.8 persons) in 2016 (C&SD, 2018a). According to the Population By-census 2016, the median per capita floor area of Hong Kong population was 161.4 square feet. The average per capita floor area of the SDU was 52.4 square feet, which reduced by 22.4% from 2013 (67.6 square feet) (Policy 21 Limited, 2013). The corresponding figure of the sampled SDUs was only 44.8 square feet. Both the median and mean values were below the official threshold for overcrowding housing i.e. 75.3 square feet (Hong Kong Housing Authority, 2019). It implies that it is very difficult for them to reduce the living space further. Summary statistics of the SDU samples are presented in Table 4.

[Table 4 Here]

Referring to the government's records, the SDUs in the dataset were subdivided from 104 whole-flat apartments. The average floor area of the SDUs is about 1/4 of the whole-flat apartments. Interestingly, the average monthly rent of the SDUs is about 67% of that of the whole-flats. It reflects that the unit rent per square foot increases when size decreases. Since both the SDUs and the whole-flat apartments are the same housing units, the summary statistics of most of the location, quality and time variables are the same. The only changes in the housing attributes are the number of independent toilets and the number of windows of the subject unit. Since the numbers of toilets and windows in all the whole-flat apartments are almost the same, as the minimum provisions are regulated by laws, their effects cannot be identified in the sample, and are therefore omitted. We assume the number of toilets is one for whole flats in our dataset with floor area ranges from 246.97 to 883.63 square feet.

On the contrary, the presence of an independent toilet and an openable window in SDU has been found to be valuable as they can substantially improve the living conditions. In our sample, 92% and 88% of the SDUs possess an independent toilet and a window. This study also investigates the impacts of public transportation on size elasticity and rent. With the extensive network of metro (MTR) in urban areas in Hong Kong, we measure the distance to MTR stations as a proxy. Table 5 shows the summary statistics of whole-flat apartments.

[Table 5 Here]

RESULTS

Table 6 presents the regression results of the Models 1 and 2 for SDUs and whole-flat apartments. For Model 1, floor area (*AREA*), presence of toilet (*TOILET*) and window (*WINDOW*), property management service (*PM*) are significant attributes which have positive effects on SDU rent. Besides, SDU rent of 2018 is on average 17.8% higher than that of 2016. For Model 2, building age (*AGE*) become a significant attribute and the time effects are stronger. The rateable values of whole flats increased by 16.3% from 2016 to 2017 and 24.0% from 2016 to 2018. The estimates of size elasticities of SDUs and whole flats are at about 0.30 and 0.64 respectively. The result shows that SDU rent is less responsive to size change when compared to whole flat rent, ceteris paribus, which suggests the convexity of size elasticity on unit rent. Without interacting with size effect, the effect of proximity to MTR station is insignificant in both Models 1 and 2. It is probably because the supply of SDUs is mostly within walking distance from MTR station, the proximity effect cannot be statistically differentiated.

[Table 6 Here]

Table 7 presents the regression results of Models 3 and 4 for the interactions of the proximity to public transportation to the size effects of SDUs and whole-flat apartments. For Model 3, most of the variables are of similar coefficients and significance as in Model 1. The significant and negative sign of the interaction term ($\ln(AREA_x)*\ln(MTR_x)$) implies that the size elasticity on rent decreases with the distance from MTR. Combining the above two results, they show that SDU rent is less responsive to size change when compared to whole flat rent, but more responsive to the proximity to MTR. It is in flavor of the hypotheses that SDU tenants are more willing to pay higher rent for living closer to MTR, but less willing to pay higher rent for living in a bigger unit.

[Table 7 Here]

Robustness Tests

There are several limitations in the above analysis, including (1) the non-market rental data based on RVD's appraisals, and (2) the potential selection bias of the SDU samples, which are mainly in older and dilapidated buildings. We therefore further collected rental listing data from an online real estate agent website (http://28hse.com). Data were collected from one of the districts of our SDU samples for validating the RVD's appraisal results. We collected 249 valid rental listing data of private housing in Tsuen Wan District from March to May 2020. Tables 8 and 9 present the variable descriptions and summary statistics.

[Tables 8, 9 Here]

Table 10 presents the regression results of Model 4. The size elasticity is 0.69, which is highly similar to that of the whole flats in Model 2. Salable floor area (*AREA*), building age (*AGE*), distance to MTR (*MTR*) are significant rent determinants of the asking rents of apartments in Tsuen Wan District. Rents of apartments closer to Tsuen Wan West Station (*MTR_TWW*) and Tsuen Wan station (*MTR_TW*) are 12.5% to 15.4% higher than those closer to Tai Wo Hau Station (*MTR_TWH*).

We divide the observations into two equal sub-samples of small sized flats (floor area smaller than or equal to 460 square feet, Model 5) and large sized flats (floor areas larger than 460 square feet, Model 6) to re-estimate. The results suggest that the size elasticity of large sized flats (0.92) is much higher than that of small sized flats (0.61), ceteris paribus. Size elasticity on rent increases with housing size. However, housing size in formal housing markets is normally bigger than a certain threshold thus the size elasticity would not be too small. In Model 5 for example, when the small sized housing sample's size ranges from 80 to 460 square feet, the households who can afford to rent this range of housing would have a relatively higher size elasticity than SDU households, who rent SDUs in the informal housing markets of size ranges from about 50 to 133 square feet in our sample.

The distance-to-MTR variable (MTR) is found to impose an -0.08% and -0.10% impacts on housing rents for every 1% increase in the distance to the nearest metro station for larger-sized and smaller-sized flats. It reflects a higher implicit price for the proximity to public transportation for smaller-sized households, and it also agrees with the classical consumer substitution theory that low-income households choose to live closer to the public transportation, but the unit housing rent per square foot is higher, they have to sacrifice more living area.

[Table 10 Here]

The results show the importance of accessibility for low-income households in their residential location choice to an extent that they are sacrificing housing size and living environment to make trade-off(s) for living at the proximity to metro stations. It explains why social housing schemes can sometimes result in spatial mismatch and residential immobility, such as in resettlement policies (Tiwari, 2016) and social housing policies (Kain, 1992; Ong & Miller, 2005; Taylor & Ong, 1995; Zhou, Wu, & Cheng, 2013) when the residents are from low-income households. The locations of social housing and its commuting cost are of critical importance to low-income households. If the social housing units are far away from the city centres or metro stations, the consequence of lower residential mobility can cause a less efficient labor market, which is detrimental to economic growth (Hardman & Ioannides, 1999) and households' resilience to economic shocks (Englund & Ioannides, 1997).

Cities are facing an ever-increasing demand for land to accommodate their rising population, and there is an urgent need to stimulate sustainable and inclusive economic growth in urban space (World Bank, 2018). Promoting effective land use, including how to subdivide land and building structure for higher density use, is considered essential to reducing urban land supply pressure, especially in urban cores (Wang et al., 2019). Efficient commuting infrastructure, such as mass transit railways, is built to connect people and job opportunities. Densification of cities with efficient railways are even considered as a sustainable model of urban development (Pelczynski & Tomkowicz, 2019). However, people may not realise that even when land is subdivided into smaller parcels, building structures are higher-rise and subdivided into smaller units, the housing rents at the urban cores can be more unaffordable due to the consumer substitution effect. The SDU in Hong Kong is a case in point to illustrate the consequences of a city densification process. Hong Kong has been the most unaffordable city in the previous nine years (Demographia, 2020), it's housing units are also the smallest in the world (Keegan, 2018). High-rise residential buildings with about 50 storeys are typical in the city, micro or nano flats of just 120 square feet (11 square meters) in gross floor area are nowadays commonly built in new developments. One in eight homes sold is a nano apartment. Kwan (2021) reported that in 2019, 13% of apartments sold were less than 260 square feet (24 square meters). The average market price of these nano flats in the end of 2020 was about HK$5 million (US$645,000).

CONCLUSIONS

This paper is the first empirical test on the convexity of size elasticity on rent by studying the micro-units in the informal housing markets of Hong Kong. Our argument is that only when housing size is small enough will the size elasticity on rent be manifested. SDUs in Hong Kong provide a natural experiment for researchers to empirically examine the actual effects when housing size is excessively small. Compared with formal housing units, SDUs in the informal housing markets are relatively limited in supply and there are fewer close substitutes (housing units with good accessibility but at an affordable rental level for low-income households). This paper hypothesizes that the size elasticity of informal housing is more inelastic than formal housing units. The results echo the hypothesis by showing that the size elasticity of SDUs is about half of that of whole flats in formal housing market (0.30 and 0.64).

We deploy the data of 200 SDUs and 104 whole-flat apartments from which the SDUs were subdivided. The results show that in normal whole-flat apartments, 1% change in housing size causes 0.64% change in rent, but the corresponding effect is only 0.30% in SDUs, ceteris paribus. The average sizes of the whole-flat apartments and the SDUs in the sample are 527 square feet and 133 square feet respectively. In other words, the size elasticity of a SDU of about ¼ of the average size of the whole-flat is about ½ that of the whole flat. The empirical results are in favour of the hypothesis that smaller sized housing units are more size inelastic on rent, ceteris paribus. We also conduct a robustness test by deploying the data of the rental listings of one of the surveyed districts. The test reinforces the findings in the informal housing sector. The results reveal the differences in the determining factors between large-sized and small-sized units as well as formal and informal housing.

We further found that SDU rent is less responsive to size change when compared to whole flat rent, but more responsive to the proximity to MTR. It is in favour of the hypotheses that SDU tenants are more willing to pay higher rent for living closer to MTR, but less willing to pay higher rent for living in a bigger unit. One of the major limitations of this study is the small sample size, as SDUs are irregular housing units. Besides, it would offer a more thorough picture on size elasticity if SDUs, which are located in other districts from suburban areas, can also be included in the analyses. The policy implication of this study is on the importance of accessibility for low-income households in their residential location choice. The results reflect that they are living at the proximity to metro stations at the expense of the housing size and living environment.

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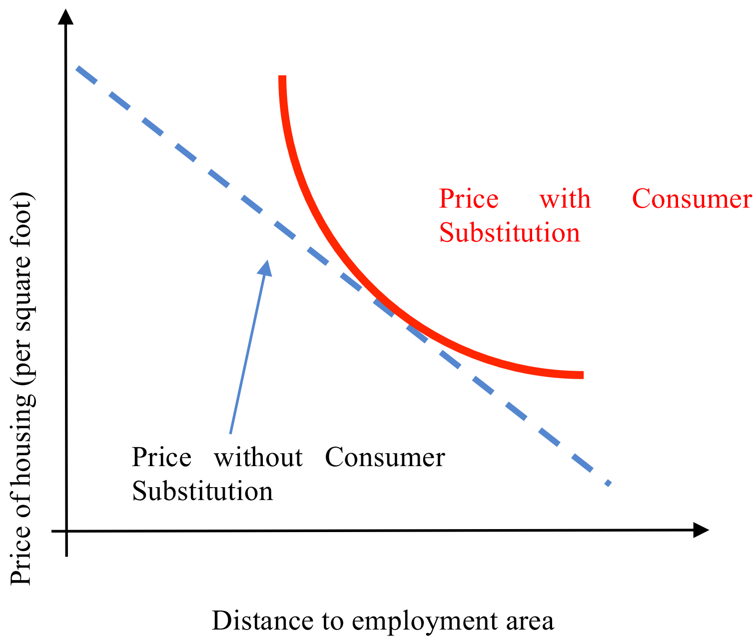

Figure 1. Consumer Substitution and Convex Housing-Price Curve

Source: simplified from Figure 6-7 of O'Sullivan (2012) – "Consumer substitution generates a convex rather than a linear housing-price curve. As distance (x) decreases and the price rises, housing consumption (square feet of space) decreases, increasing the slope of the curve (in absolute value)" (p.142)

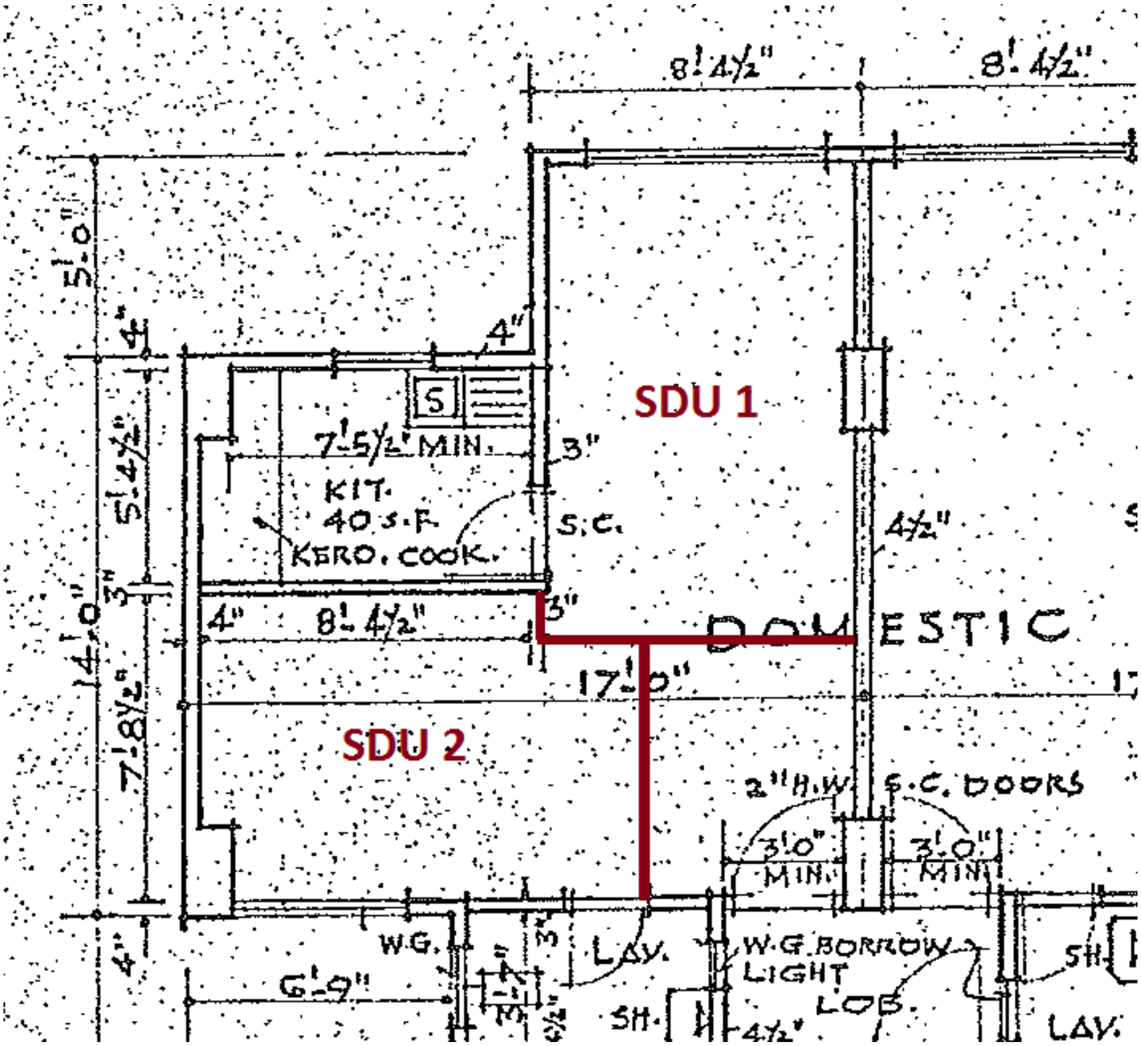

Figure 2. An Example of a Flat Subdivided into Two SDUs

Source of building plan: Buildings Department, the Government of Hong Kong Special Administrative Region

Figure 2 is extracted from the official record plan of one of the sampled flats which was subdivided into two SDUs, viz. SDU 1 and SDU 2 (the subdivision lines in red are added by the authors after conducting an on-site survey). They share the main entrance but there is a window and a kitchen in SDU 1, but no kitchen in SDU 2. The sizes of SDU 1 and SDU 2 are about 12 square meters and 8 square meters

Table 1. Size elasticity on unit rent

Reference	City/Country	Housing Type	Size Elasticity on Unit Rent
Cui, Gu, Shen, and Feng (2018)	Beijing/China		-0.477
Buchel and Hoesli (1995)	Geneva/Switzerland	Apartment (unsubsidized and subsidized housing)	-0.17 / -0.09

Hoesli (1997)	Bordeaux/France	Apartment	-0.378
Djurdjevic, Eugster, and Haase (2008)	Various Municipalities of Switzerland		-0.37
Löchl and Axhausen (2010)	Zurich		-0.223
Leung & Yiu (2019)	Hong Kong	SDU	-0.8 to -0.7
Hui, Liang, and Yip (2018)	Hong Kong	SDU / Formal Housing	-0.225 / -0.019
Huang (2017)	Hong Kong	SDU / Formal Housing	+0.863 / -0.916

Table 2. Variable descriptions

Variable	Description
$RENT_u$	Monthly SDU rent in HK$ adjusted to October of the previous year by RVD housing rental index
$RENT_f$	Monthly rateable value from Rating and Valuation Department in HK$
$AREA_x$	Saleable floor area in square foot
AGE_x	Building age
FLR_x	Floor level
MTR_x	Distance to the nearest MTR station in meter
OC_x	Dummy variable = 1 if the unit is located in building with owners' corporation, 0 if otherwise
PM_x	Dummy variable = 1 if the unit is located in building with property management services, 0 if otherwise
$TOILET_x$	Dummy variable = 1 if the unit is with non-shared toilet, 0 if otherwise
$WINDOW_x$	Dummy variable = 1 if the unit has openable window, 0 if otherwise
D_KTS_x	Dummy variable = 1 if the unit is located in Kwai Tsing District, 0 if otherwise
D_KLC_x	Dummy variable = 1 if the unit is located in Kowloon City District, 0 if otherwise
D_KTO_x	Dummy variable = 1 if the unit is located in Kwun Tong District, 0 if otherwise
D_SSP_x	Dummy variable = 1 if the unit is located in Sham Shui Po District, 0 if otherwise
D_TW_x	Dummy variable = 1 if the unit is located in Tsuen Wan District, 0 if otherwise
D_CW_x	Dummy variable = 1 if the unit is located in Central and Western District, 0 if otherwise (Reference group)
2016_x	Dummy variable = 1 if the valuation reference year of adjusted SDU rental value or rateable value is 2016, 0 if otherwise (Reference group)
2017_x	Dummy variable = 1 if the valuation reference year of adjusted SDU rental value or rateable value is 2017, 0 if otherwise
2018_x	Dummy variable = 1 if the valuation reference year of adjusted SDU rental value or rateable value is 2018, 0 if otherwise

Table 3. Percentage of SDUs by Districts

Districts	Percentage of SDUs (from highest to lowest)
Yau Tsim Mong	22.0%
Sham Shui Po	15.8%
Kowloon City	9.7%
Tsuen Wan	6.9%
Kwun Tong	5.4%
Central and Western	5.0%

Notes: These six District Council Districts contain 63.5% of the SDUs, out of 12 District Council Districts. This study covers all District Council Districts in Kowloon except Wong Tai Sin District (its SDU number was not released in the government report (C&SD, 2018b)). The study areas also include Tsuen Wan and Kwai Tsing Districts, which were the top two districts with the most SDUs in the New Territories in 2016.

Source: C&SD (2018b),

Table 4. Summary statistics of Model 1 (SDUs)

Variable	Mean	Std. Dev.	Minimum	Maximum
$RENT_u$	4874.111	1,339.867	1,756.143	8,466.628
$AREA_u$	133.388	50.146	26.523	479.410
AGE_u	51.310	5.630	36.000	60.000
FLR_u	5.475	3.928	1.000	22.000
MTR_u	840.110	337.055	30.000	1,600.000
OC_u	0.705	0.457	0.000	1.000
PM_u	0.125	0.332	0.000	1.000
$TOILET_u$	0.920	0.272	0.000	1.000
$WINDOW_u$	0.880	0.326	0.000	1.000
D_KTS_u	0.265	0.442	0.000	1.000
D_KLC_u	0.145	0.353	0.000	1.000
D_KTO_u	0.240	0.428	0.000	1.000
D_SSP_u	0.010	0.100	0.000	1.000
D_TW_u	0.280	0.450	0.000	1.000
D_CW_u	0.060	0.238	0.000	1.000
2016_u	0.320	0.468	0.000	1.000
2017_u	0.355	0.480	0.000	1.000
2018_u	0.325	0.470	0.000	1.000

Table 5. Summary statistics of Model 2 (whole-flat apartments)

Variable	Mean	Std. Dev.	Minimum	Maximum
$RENT_f$	7,296.282	2,638.851	3,400.000	19,240.000
$AREA_f$	526.787	155.176	246.967	883.628
AGE_f	50.971	5.596	36.000	60.000
FLR_f	5.769	4.158	1.000	22.000
MTR_f	852.096	343.797	30.000	1,600.000
OC_f	0.731	0.446	0.000	1.000
PM_f	0.125	0.332	0.000	1.000
D_KTS_f	0.250	0.435	0.000	1.000
D_KLC_f	0.163	0.372	0.000	1.000
D_KTO_f	0.279	0.451	0.000	1.000
D_SSP_f	0.010	0.098	0.000	1.000
D_TW_f	0.240	0.429	0.000	1.000
D_CW_f	0.058	0.234	0.000	1.000
2016_f	0.433	0.498	0.000	1.000
2017_f	0.288	0.455	0.000	1.000
2018_f	0.279	0.451	0.000	1.000

Table 6. Regression results of Models 1 & 2

Variable	Coeff.	Std. Error		Coeff.	Std. Error	
	Model 1 (SDUs)			Model 2 (Whole Flats)		
Constant	7.2544	0.9577	***	11.0395	1.4286	***
$\ln(AREA_x)$	0.2953	0.0487	***	0.6389	0.0985	***
$\ln(AGE_x)$	-0.1206	0.2221		-1.2880	0.3166	***
$\ln(FLR_x)$	0.0399	0.0278		-0.0019	0.0387	
$\ln(MTR_x)$	-0.0593	0.0815		-0.1285	0.1236	
$TOILET_u$	0.2598	0.0714	***			
$WINDOW_u$	0.0807	0.0447	*			
OC_x	-0.0383	0.0525		0.1018	0.0746	
PM_x	0.1962	0.0669	***	-0.0615	0.0992	
2017_x	0.0445	0.0374		0.1628	0.0548	***
2018_x	0.1781	0.0407	***	0.2402	0.0602	***
D_KTS_x	0.1574	0.2275		-0.2504	0.3454	
D_KLC_x	0.1263	0.2326		-0.4197	0.3508	
D_KTO_x	0.3436	0.1809	*	-0.3914	0.2734	
D_SSP_x	-0.1433	0.1846		-0.5742	0.2644	**
D_TW_x	0.1944	0.2124		-0.4113	0.3228	
Dependent Variable	$\ln(RENT_u)$			$\ln(RENT_f)$		
Number of observations	200			104		
Adjusted R-squared	0.5859			0.5810		

Notes: ***, **, * represent the estimate is significant at the 1%, 5% and 10% levels

Table 7. Regression results of Models 3 & 4

Variable	Coeff.	Std. Error		Coeff.	Std. Error	
	Model 3 (SDUs)			Model 4 (Whole Flats)		
Constant	1.7623	2.3026		-9.6879	7.8787	
$\ln(AREA_x)$	1.3335	0.4000	***	4.2884	1.3690	***
$\ln(AGE_x)$	-0.0559	0.2201		-1.5199	0.3184	***
$\ln(FLR_x)$	0.0620	0.0287	**	-0.0157	0.0378	
$\ln(MTR_x)$	0.7703	0.3273	**	3.1230	1.2226	**
$\ln(AREA_x) * \ln(MTR_x)$	-0.1583	0.0605	***	-0.5528	0.2068	***
$TOILET_u$	0.2227	0.0718	***			
$WINDOW_u$	0.0900	0.0442	**			
OC_x	-0.0564	0.0521		0.0577	0.0740	
PM_x	0.2103	0.0661	***	-0.1014	0.0972	
2017_x	0.0552	0.0371		0.1606	0.0530	***
2018_x	0.1814	0.0401	***	0.2450	0.0583	***
D_KTS_x	-0.0785	0.2415		-0.0466	0.3428	
D_KLC_x	-0.0935	0.2439		-0.1080	0.3589	
D_KTO_x	0.1524	0.1926		-0.1802	0.2761	
D_SSP_x	-0.1947	0.1828		-0.9969	0.3008	***
D_TW_x	-0.0266	0.2255		-0.1749	0.3246	
Dependent Variable	$\ln(RENT_u)$			$\ln(RENT_f)$		
Number of observations	200			104		
Adjusted R-squared	0.5986			0.6078		

Notes: ***, **, * represent the estimate is significant at the 1%, 5% and 10% levels.

Table 8. Variable descriptions (Tsuen Wan District)

Variable	Description
RENT	Monthly rent in HK$
AREA	Saleable floor area in square foot
AGE	Building age
MTR	Distance to the nearest MTR station in meter
MTR_TW	Dummy variable =1 if the nearest MTR station to the apartment is Tsuen Wan Station, 0 if otherwise
MTR_TWW	Dummy variable =1 if the nearest MTR station to the apartment is Tsuen Wan West Station, 0 if otherwise
MTR_TWH	Dummy variable =1 if the nearest MTR station to the apartment is Tai Wo Hau Station, 0 if otherwise (Reference group)
OC	Dummy variable = 1 if the unit is located in a building with owners' corporation, 0 if otherwise
PM	Dummy variable = 1 if the unit is located in a building with property management services, 0 if otherwise
M03	Dummy variable = 1 if the rental listing is in March 2020, 0 if otherwise (Reference group)
M04	Dummy variable = 1 if the rental listing is in April 2020, 0 if otherwise
M05	Dummy variable = 1 if the rental listing is in May 2020, 0 if otherwise

Table 9. Summary statistics (Tsuen Wan District)

Variable	Mean	Std. Dev.	Minimum	Maximum
RENT	16,053.330	5,307.280	5,500.000	39,000.000
AREA	484.755	168.589	80.000	1,290.000
AGE	25.859	12.719	1.000	57.000
MTR	1141.124	554.372	210.000	2,800.000
MTR_TW	0.153	0.360	0.000	1.000
MTR_TWW	0.807	0.395	0.000	1.000
MTR_TWH	0.040	0.197	0.000	1.000
OC	0.735	0.442	0.000	1.000
PM	0.795	0.404	0.000	1.000
M03	0.016	0.126	0.000	1.000
M04	0.663	0.474	0.000	1.000
M05	0.317	0.466	0.000	1.000

Table 10. Regression results (Tsuen Wan District)

	Model 4 (All Data)			Model 5 (Small Sized Flats)			Model 6 (Large Sized Flats)		
Variable	Coeff.	Std. Error		Coeff.	Std. Error		Coeff.	Std. Error	
Constant	6.1034	0.1561	***	6.6155	0.1854	***	4.4868	0.3585	***
ln(*AREA*)	0.6895	0.0182	***	0.6074	0.0236	***	0.9249	0.0506	***
ln(*AGE*)	-0.0655	0.0130	***	-0.0493	0.0163	***	-0.0690	0.0189	***
ln(*MTR*)	-0.1007	0.0172	***	-0.1057	0.0209	***	-0.0800	0.0264	***
MTR_TW	0.1537	0.0381	***	0.1062	0.0421	***	0.1431	0.0585	***
MTR_TWW	0.1253	0.0328	***	0.0835	0.0392	***	0.1380	0.0470	***
OC	0.0114	0.0153		-0.0217	0.0218		0.0180	0.0207	
PM	-0.0301	0.0165	*	-0.0223	0.0198		-0.0127	0.0252	
M04	0.1017	0.0451	**	0.1163	0.0494	**	0.0592	0.0754	
M05	0.1090	0.0461	**	0.1206	0.0496	**	0.0394	0.0773	
Dependent Variable	ln(*RENT)*								
Number of observations	249			125			124		
Adjusted R-squared	0.9034			0.8899			0.8187		

Notes: ***, **, * represent the estimate is significant at the 1%, 5% and 10% levels