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Development of price models for architectural and environmental quality for residential developments in Hong Kong

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Abstract

Factors affecting a residential unit’s price are always of interest to homebuyers and building developers, especially in a city like Hong Kong which is known for expensive housing. Literature review indicates that the governing factors can be categorized into architectural and environmental attributes. Among different methods commonly used for pricing, the hedonic price approach is viewed as the most suitable. However, the successful use of this method requires that homebuyers know and choose the attributes. Whilst choosing architectural attributes are not a problem for homebuyers, the same does not apply to environmental attributes. Previous studies by the authors have proposed some simple indicators for quantifying the environmental attributes. Based upon the developed performance indicators and the transaction records of two representative housing estates (Royal Ascot = RA and City One Shatin = COS), details of the properties, including transaction prices, architectural particulars and environmental characteristics were numerically transformed for the hedonic price analysis. The analysis results revealed that the willingness to pay (percentage of house price in parenthesis) for architectural and environmental attributes was HK$302.3/ft² (5.8%) and HK$886.8/ft² (28.2%), respectively, for RA and HK$1672.7/ft² (31.6%) and HK$1115.5/ft² (3.5%) for COS. It was found that elasticity of substitution (ES) of environmental attributes contributed 3.4–13.3% of the property price, compared to 0.6–5.5% for architectural attributes.

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Introduction

A residential property's market value is determined by combinations of site-specific and property-specific characteristics. Site-specific characteristics, described by site locations and availability of amenities in close vicinity, are often set by the town planning group (HKPSG, 2011), which is a constraint beyond the control of site planners and architects. Property-specific characteristics, on the contrary, are not stipulated in local codes and regulations; site planners and architects are generally allowed to design the construction the way they deem proper (EPD, 2006; JPN1, 2001; JPN2, 2002; PNAP, 2013). These characteristics, contributed by architectural and environmental attributes, therefore, vary significantly in different residential units.

Hong Kong people spend a large amount of their income on housing. According to the global house-price indicators published in "The Economist" in 2011, Hong Kong tops the world in residential property prices. Results of the 2009/2010 household expenditure survey also showed that the weight of expenditure Hong Kong people incur on housing was the highest among expenses under all heads, accounting for over 32% of the total household expenditure. Thus the influence of a residential property’s characteristics on its market value is of particular importance to Hong Kong people when making home buying decisions, and on the contrary, to building developers when making investment decisions.

Over the years, several studies have investigated the influence of different factors on residential property prices. Harris (1989), Krashinsky and Milne (1987) and Tse (1996) found that economic conditions play a significant role in property price increases. Many others have found that government policies on town planning (Sagalyn & Sternlieb, 1973) land supply (Hannah, Kim, & Mills, 1993) and tax system (Bramley, 1993) affect property prices significantly. However, economic and government policies impact the residential property market as a whole only, while market value of individual residential units is affected more by site-specific characteristics. Some studies have examined influence of individual property-specific features also. However, little seems to have been done for investigating the relative and combined influence of different property-specific characteristics.
In the context of impact of different property-specific characteristics on market value, the willingness to pay (WTP) (Banfi, Farsi, Filippini, & Jakob, 2005; Jim & Chen, 2006; Kim, Phipps, & Anselin, 2003; Okoko, 2004) and elasticity of substitution (ES) concepts (Ahmad, Choi, & Ko, 2013; Hannah et al., 1993; Pryce, 1999) are often adopted in relevant research. In this study, the hedonic price method is adopted for determining the market value of each property-specific attribute. However, use of the hedonic price method requires development of performance indicators that are known to homeowners. This is less of a problem for architectural attributes which can easily be understood by homeowners but is a problem in case of environmental attributes. Accordingly, a series of studies has been done by the authors for developing performance indicators for quantifying a residential unit’s environmental qualities (Fung & Lee, 2011, 2012, 2014). Through the use of the hedonic price method, the marginal WTP and ES for each architectural and environmental attribute are determined for the information of homeowners and building developers.

**Factors affecting residential property prices**

That economic and government policies affect the residential property market as a whole has been documented widely. That an individual residential property’s market price is affected by combinations of site-specific and property-specific factors also is indicated by studies reviewed below.

**Site-specific factors**

Tse and Love (2000) stated that property price could be raised by availability of car park, shopping center and club house, etc. Hui, Chau, Pun, and Law (2007) found that the availability of a private club house within an estate increases the sale value of an apartment by about 3.5%. These findings explain why in the last few years, nearly all new residential estates have club houses and developers often use them as one of the key selling points. Moreover, Jud and Watt (1981) identified that districts with reputable schools have higher property value compared with other districts. Hui et al. (2007) further identified that each additional reputable secondary school located in the proximity of a property leads to an average of 0.1% increase in house price. Mok, Chan, and Cho (1995) pointed out those houses with good security provisions are viewed as more valuable.

**Property-specific factors**

Property-specific characteristics can be classified into architectural and environmental attributes. Environmental attributes, according to several building environmental assessment schemes (BEAM Interiors, 2008; BEAM Plus, 2010) can further be classified into occupant-specific and property-specific issues. The occupant-specific issues include thermal comfort, electromagnetic environment and indoor environmental quality (IEQ) management, which obviously do not affect property prices. Thus, as far as property price is concerned, only property-specific issues are considered. They include indoor air quality, quality of view and other health and safety related features such as natural ventilation, acoustic performance and daylight performance.

**Architectural attributes**

With regard to the influence of architectural attributes on property price in a high-density city like Hong Kong, Tse and Love (2000) revealed that floor area has a positive influence on property price. However, valuation of larger units does not increase proportionally with area of medium quality residential housing because the demand for small units is relatively higher than large units since homebuyers cannot afford the higher property price. Mok et al. (1995) illustrated that valuation of a property is most sensitive to changes in the age of a building and the floor level. They found that valuation of a property is inversely related to the age of the building and higher floors have a positive effect on price. Hui et al. (2007) conducted a similar research and found that a younger flat has a higher sale price than an older one, other attributes being identical. On average, it was observed that price goes up by 1.6% if a flat is a year younger; price decreases by 0.3% as one goes one floor down. This is somewhat consistent with the pricing strategy of developers as revealed from the sale price of the first hand residential properties markets.

**Environmental attributes**

Much literature has reviewed the effects of environmental attributes on property prices. The earliest work was carried out by Ridker and Henning (1967) to study the relation between indoor air quality (IAQ) and property prices in the St. Louis metropolitan area. They concluded that air pollution was a relatively significant factor in explaining residential property values. Harrison and Rubinfeld (1978) later estimated the marginal value of clean air for property prices in the Boston metropolitan area. It was found that the value of clean air was positive and the effect was positively correlated to household income. With regard to the effect of indoor particulate matter on property prices, Diamond (1980) and Li and Brown (1980) found a significantly negative effect. Chattopadhyay (1999) pointed out that residents in Chicago were willing to pay more for reducing exposure to pollution caused by air particulate (PM10) and sulfur dioxide. A regression analysis by Kim et al. (2003) also showed that the marginal WTP for a 4% air quality improvement was about 1.4% of the mean house value. To conclude, people prefer a place with better IAQ despite a higher cost.

IAQ and natural ventilation performance are closely related. Chao, Tung, and Burnett (1997) studied the influence of different ventilation rates on indoor radon levels at 12 residential sites in Hong Kong. It was reported that the ratio of indoor to outdoor radon level was 46.5 when the ventilation rate was around 0.2 air changes per hour (ACH). However, when the ventilation rate was increased to greater than 3 ACH, the indoor radon level was close to the outdoor radon level. Murakami, Kato, Ooka, and Shiraishi (2004) studied two residential building models with and without voids in buildings. The results indicated that the model with voids improves natural ventilation effectively and thus saves 2.8% of energy used for air-conditioning compared with the model without natural ventilation. Given the positive contribution of natural ventilation to energy usage and IAQ, better natural ventilation undoubtedly has an impact on the property value.

The acoustic environment of an indoor space is often associated with traffic noise, which has commonly been regarded as a negative externality that causes inevitable sufferance. The higher the traffic noise, the lower will be the property value. Nelson (1982) studied the impact of traffic noise by hedonic price method. The result was represented by a noise sensitivity depreciation index (NSDI) that relates the percentage depreciation in property price induced by each decibel (dB(A)) of noise above a threshold level. It was found that a house with a background noise level of 75 dB(A) was valued 8% less than a house with a noise level of 55 dB(A) and thus the corresponding NSDI was 0.4. Wilhelmsson (2000) conducted a detailed study on the correlation between traffic noise and the value of single-family houses in Sweden. His empirical analysis found an average drop of 0.6% in property price for each increase in dB(A) or a total discount of 30% in price for a house in a noisy location compared to a house in a quiet zone.
Daylight is one important environmental attribute that is critical to occupant comfort and health. Levermore and Meyers (1996) conducted a survey aimed at quantifying occupants' perceptions of interior environments. The questionnaire revealed that daylight was one of the important issues. Ossama (1997) carried out another survey to find the correlation between indoor environment and worker productivity. He concluded that daylight is an important factor contributing to enhancement of worker productivity. Workers appreciate working in the presence of daylight which makes them feel more comfortable. It is therefore evident that daylight performance has a monetary value.

The view that can be seen from a residential unit is an important factor that affects its price. Previous studies have concluded that a good view is one of the main externalities. Homebuyers were found willing to pay an extra 8–60% for a property with a good view (Benson, Hansen, Schwartz, & Smersh, 1998; Brown & Pollakowski, 1977; Rodríguez & Sirmans, 1994; Tse & Love, 2000). Benson et al. (1998) found that the extent of influence depends on types and quality of views. It was found that the value of a view varies inversely with distance from the waterfront. Tse and Love (2000) found that a cemetery view lowers the property price.

Governing factors

It is evident from the above that a residential property's market price is directly or indirectly related to site-specific as well as property-specific factors. However, in the same residential estate, site-specific factors, and some of the architectural attributes, including age of building and floor layout are identical. Thus major factors affecting a residential property's market price are the remaining architectural attributes (i.e. floor area, floor level, window area and orientation) and also the environmental attributes, i.e. acoustics, indoor air quality, quality of view, daylight performance and natural ventilation performance.

Methodology

This study adopts the hedonic price method to determine the marginal WTP and ES for each architectural and environmental attribute for the information of homebuyers and building developers in Hong Kong, based upon performance indicators developed earlier by the authors (Fung & Lee, 2011, 2012, 2014) and representative transaction records.

The hedonic price method

Previous studies have identified that the contingent valuation survey method (Altar, 1994; Kang, Haab, & Interis, 2013; Torres, Green, & Ortúzar, 2013), travel costs method (Chae, Wattage, & Pascoe, 2012; Gürliük & Rehber, 2008) and hedonic price method (Chan, So, Tang, & Wong, 2012; Cottelee & Kooten, 2012) are the most used for determining the implicit price of an attribute for substitution with a less desired option.

Among the three, the contingent valuation method is often considered not reliable because it is based on what people say they will do rather than what people are observed to do (Kang et al., 2013) and the travel cost model method is only good for valuating site-specific attributes (Chae et al., 2012; Gürliük & Rehber, 2008). The hedonic price method estimates value based on actual choices, is considered the most suitable for valuating price for various architectural and environmental attributes (Cottelee & Kooten, 2012).

In the use of the hedonic price method, a residential property’s market price (PRI) is represented as a function of “n” attributes, i.e. $PRI = f(X_1, \ldots, X_n)$ for multiple regression analysis for analyzing the marginal WTP of the attributes. This appraisal methodology was set by Eisenlauer (1968). After his article, many other researchers have explored the use of multiple regression analysis for property prices analysis (Rosen, 1974). However, to ensure marginal WTP is determined based on actual choices, the successful use of this method is subject to: i) availability of reliable property prices; and ii) homebuyers knowing and choosing the attributes (Collins, Scorcu, & Zanola, 2009).

In respect of reliability of source of data, property transaction records (property details and selling prices) in Hong Kong are readily available through many sources (Centreline Property, 2013; Midland Realty, 2013) and so can be good indication of property prices. But considering Hong Kong residential property price fluctuates month by month and year by year due to different reasons, transaction records to be selected must be representative and should be free from impact of economic conditions and government policies. For knowing and choosing the attributes, unfortunately, most homebuyers do not have the background required to understand the physical meaning of the attributes, particularly the environment-related issues. Hence, simple indicators for representing the performance of various environmental attributes need to be developed.

Performance indicators

The authors of this paper have in the past worked on developing performance indicators for quantifying the studied environmental attributes. However, considering that the development details have been reported earlier, to avoid duplication, only the performance indicators are given below:

(a) The logarithm of the distance from road (Log R) to be used as the common performance indicator for traffic-induced noise and indoor air quality. It was developed based on field measurements and regression analysis.

(b) The average angle of unobstructed sky ($\overline{\theta}$) to be used as a performance indicator for assessing quality of view and daylight performance. It was developed based on ECOTECT (Mash, 2010) simulations and an extensive site survey.

(c) The mode of ventilation (cross or single-sided) which has been identified as the most influential parameter affecting natural ventilation performance of a residential unit. It was developed based on CFD simulations, field measurements and statistical analysis.

Representative transaction records

Hong Kong’s residential property market is greatly influenced by changes in economic outlook and governmental policy factors. In early 1990s, property prices rose strongly reflecting a positive impact of different factors including booming economic activity, low interest rates, and strong increases in the number of house-holds due to immigration from China and moderate growth in public housing supply. But starting from 1997, there was a sharp decline in property prices due to the Asian financial crisis. In the subsequent years, property prices continued to drop due to combinations of several reasons: contraction of economic activities; the ‘85,000’ housing plan (supplying 85,000 new units per annum) announced by the Hong Kong government; and SARS\footnote{SARS stands for Severe Acute Respiratory Syndrome. SARS in Hong Kong killed almost 300 people over a four month period.} occurrence in 2003. To enable a focused evaluation of the influence of the...
identified factors on Hong Kong residential property prices, a specific year's transaction records with the smallest fluctuation in prices needs to be identified for this study.

In Hong Kong, movements of property prices are often measured by the annual Private Domestic-Price Indices compiled by the Rating and Valuation Department (RVD, 2010). The monthly price indices for the period 2000–2005, illustrating that the smallest change was in 2003 (−5.654) and this was followed in 2005 (−9.146). The small variation in price indices in 2003 could be explained by the occurrence of SARS during which the property market was seriously affected. Besides the substantial drop in price impacts, the impact was also reflected in the drop in number of sale and purchase agreements, which was 71,576 in 2003 as opposed to 103,362 in 2005 (Land Registry, 2010).

Considering the change of dependent and independent variables (VENT and ORI), the dummy variable method was adopted for qualitative variables. To deal with the qualitative factors in the model, the mean angle of unobstructed sky ($\theta$), which was identified as a simple indicator for quantifying daylight performance and view obstruction.

It is worth mentioning that the price models consist of a mix of quantitative and qualitative variables. To deal with the qualitative variables (VENT and ORI), the dummy variable method was adopted to assign the value 0 or 1 to indicate the absence or presence of a particular condition except the base group against which the comparisons are made. In this case, the less preferred conditions identified in previous studies were chosen as the base group, i.e. west facing windows and single-sided ventilation mode. Accordingly, for ORI, only north (N), south (S) and east (E) were coded, and likewise for VENT, only cross ventilation was coded.

### Hedonic price analysis

The hedonic price method provides different forms of equations for determining the market value of an attribute. While there is no theoretical linkage between the functional notation and a specific functional form, linear and semi-log forms are generally used for studies on housing markets (Jim & Chen, 2006).

#### Form of the price models

For the linear model, a bundle of architectural and environmental attribute characteristics of a residential unit can be related to its market price as follows:

$$PRI = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + \cdots + a_n X_n$$  

where $PRI =$ market price of a residential unit (HK$/\text{ft}^2$); $X_n =$ attribute characteristics of a residential unit; $a_n =$ marginal WTP for each $X_n$; $a_0 =$ constant.

The semi-log model can be used to relate the unit change in market price of a residential unit for unit change of each constituent variable $X$.

$$\ln PRI = a'_0 + a'_1 \ln X_1 + a'_2 \ln X_2 + a'_3 \ln X_3 + \cdots + a'_n \ln X_n$$  

(2)

Considering the change of dependent and independent variables

$$\Delta \ln PRI = a'_0 + a'_1 \Delta \ln X_1 + a'_2 \Delta \ln X_2 + a'_3 \Delta \ln X_3 + \cdots + a'_n \Delta \ln X_n$$  

(3)

By conducting partial derivatives of Equation (2) with respect to each constituent variable ($X_n$)

$$\frac{\partial PRI}{\partial PRI} = a'_1 \frac{\partial X_1}{X_1} + a'_2 \frac{\partial X_2}{X_2} + a'_3 \frac{\partial X_3}{X_3} + \cdots + a'_n \frac{\partial X_n}{X_n}$$  

(4)

Equation (4) shows that the physical meaning of $a'_n$ is the percentage change in market price of a residential unit for unit change of $X$, in which other words, is the ES between the independent variable and the market price of a residential unit.

As the dependent variable cannot be log-transformed (e.g. $X_3$, $X_n$, etc.), the semi-log form of the price model Equation (2) becomes

$$\ln PRI = a'_0 + a'_1 \ln X_1 + a'_2 \ln X_2 + a'_3 \ln X_3 + \cdots + a'_{n-1} \ln X_{n-1} + a'_n X_n$$  

(5)

### Selection of model variables

The dependent variable, i.e. market price of a residential unit (PRI) and five independent variables included in this study are summarized in Table 2.

| Table 1 Price indices of private domestic premises for 2000–2005. |
|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Month             | Year            | 2000            | 2001            | 2002            | 2003            | 2004            | 2005            |
| Jan               | 75.5            | 80.7            | 74.1            | 63.6            | 69.5            | 85.7            |
| Feb               | 75.5            | 80.2            | 73.9            | 63.4            | 73.2            | 89.4            |
| Mar               | 75.3            | 82.1            | 73.3            | 61.2            | 78.1            | 94.6            |
| Apr               | 73.9            | 82.2            | 72.3            | 60.5            | 79.4            | 95.4            |
| May               | 90.3            | 80.5            | 72.4            | 59.7            | 77.5            | 95.3            |
| Jun               | 86              | 80.9            | 71.9            | 59.3            | 74.7            | 92.9            |
| Jul               | 86.6            | 80.2            | 70.9            | 58.4            | 74.9            | 92.8            |
| Aug               | 87.2            | 78.5            | 68.3            | 58.6            | 77.6            | 93.9            |
| Sep               | 88.2            | 77.2            | 66.7            | 60.9            | 80.9            | 94              |
| Oct               | 87              | 74.1            | 65.4            | 63.4            | 94.1            | 91.8            |
| Nov               | 83.7            | 73.6            | 65.1            | 64.3            | 82.7            | 88.5            |
| Dec               | 81.8            | 73.8            | 64.8            | 65.4            | 83.3            | 90.1            |
| Maximum           | 90.3            | 82.2            | 74.1            | 65.4            | 94.1            | 95.4            |
| Minimum           | 73.9            | 73.6            | 64.8            | 58.4            | 69.5            | 85.7            |
| Standard Deviation| 5.957           | 3.217           | 3.622           | 2.378           | 6.236           | 3.024           |
| Variance          | 35.49           | 10.35           | 13.12           | 5.654           | 38.89           | 9.146           |

| Variable Details | Unit/Code |
|------------------|-----------|
| PRI              | Market price of the residential unit |
| FLA              | Floor area of the residential unit  |
| ORI              | Living room window orientation – North |
| E                | Living room window orientation – East |
| S                | Living room window orientation – South |
| LogR             | The logarithm of the distance from road |
| $\theta$         | Mean angle of unobstructed sky  |
| VENT             | Existence of the cross ventilation |

Based on the above, the model of Equation (5) is developed, where the coefficient $a'_1$ shows the marginal willingness-to-pay for each one unit change of architectural attribute $X_1$ to the market price of a residential unit. By examining the coefficient of FLA and ORI, the other independent variables (VENT and ORI), the dummy variable method was adopted to assign the value 0 or 1 to indicate the absence or presence of a particular condition except the base group against which the comparisons are made.
Formulation of price models

Based upon Equation (1), the correlation between properties’ market price and attribute characteristics of the residential units (the identified independent variables) can be expressed by the linear price model

\[
PRI = a_0 + a_1(\text{FLA}) + a_2(\text{ORIN}) + a_3(\text{ORIE}) + a_4(\text{ORIS}) + a_5(\text{LogR}) + a_6(\overline{\theta}) + a_7(\text{VENT})
\] (6)

where \(a_0 = \text{constant} \); \(a_1-a_7 = \text{marginal WTP} \) for each attribute.

The qualitative independent variables, i.e. ORIN, ORIE, ORIS, and VENT, have not been log-transformed and based upon Equation (5), the semi-log hedonic price model is expressed as

\[
\ln(\text{PRI}) = a'_0 + a'_1(\text{FLA}) + a'_2(\text{ORIN}) + a'_3(\text{ORIE}) + a'_4(\text{ORIS}) + a'_5(\text{LogR}) + a'_6(\overline{\theta}) + a'_7(\text{VENT})
\] (7)

where \( a'_0 = \text{constant} \); \( a'_1-a'_7 = \text{elasticity of substitution (ES) between the independent variable and market price of a residential unit.} \)

Case study estates and data collection

Two residential estates, Royal Ascot (RA) and City One Shatin (COS), adopted previously for developing the performance indicators were again chosen for the price analysis. To avoid duplication, the site-specific conditions and characteristics of these two estates are only briefly described.

RA consists of 10 blocks with 2500 units. The blocks are of around 33–40 stories and 4–8 units on each floor. There are altogether three area classes (Classes B–D); three major view types (race course, hill and building views); two ventilation modes (single-sided and cross); and four major orientations for the living room. The estate is facing the major highway serving the Northeast New Territories in Hong Kong.

COS consists of 52 blocks with nearly 10,000 units. The blocks are of around 27–33 stories and 4–8 units on each floor. There are altogether three area classes (Classes A–C); two major view types (river and building views); two ventilation modes (single-sided and cross); and four major orientations for the living room. The estate is surrounded by four major roads serving different parts of New Territories in Hong Kong.

The actual transaction data of the two case study estates in 2005 were collected from the Land Registry of Hong Kong. It was found that the average market price of RA was HK$5251/ft² while COS was HK$3146/ft². These indicate that the two estates attract different groups of homebuyers and thus the data need to be separately analyzed and likewise for the development of price models.

On collection of the transaction data, it was noted that there were data points “very distant” from the other points for unknown reasons, and thus the box plot analysis (Frigge, Hoaglin, & Iglewicz, 1989) was conducted to remove the outliers. Upon removal of the outliers, 127 (out of 143) and 1134 (out of 1139) transaction data were included in price analysis for RA and COS, respectively.

Different methods were adopted for ascertaining attribute characteristics of the residential units in the transaction records. Floor area of the residential units (FLA) was obtained directly from the transaction record. Orientations of the residential units’ living room windows (ORI) were ascertained from the map of the estates. The mean angle of unobstructed sky (\(\overline{\theta}\)) was calculated based on measurements in a 3D model, drawn based on 1:1000 digital maps. For determining road distance (R), the horizontal distance from road was checked by the use of 1:1000 digital maps, while the vertical level was found by site measurements. Finally, the absence and presence of cross ventilation (VENT) was identified from the layout plan of each residential unit.

Results

The resultant price models

Upon ascertaining the attribute characteristics of the 127 and 1134 residential units in RA and COS, linear regression analysis was performed using the statistical package, SPSS. Since this study attempts to find out the WTP and ES of the architectural and environmental attributes, all identified variables are included in the regression analysis. Accordingly, “Enter” regression method was adopted to determine the coefficients for each independent variable. The resultant price models for RA and COS are shown in Equations (8)-(11), respectively.

Linear model for RA:

\[
PRI = 3605.71 + 0.008(\text{FLA}) + 34.56(\text{ORIN}) + 451.69(\text{ORIE}) + 392.87(\text{ORIS}) + 359.47(\text{LogR}) + 523.03(\overline{\theta}) + 287.01(\text{VENT})
\] (8)

Semi-log model for RA:

\[
\ln(\text{PRI}) = 8.361 + 0.006(\text{FLA}) + 0.007(\text{ORIN}) + 0.085(\text{ORIE}) + 0.074(\text{ORIS}) + 0.133(\text{LogR}) + 0.103(\overline{\theta}) + 0.054(\text{VENT})
\] (9)

Linear model for COS:

\[
PRI = 2587.71 + 0.02(\text{FLA}) + 55.70(\text{ORIN}) + 145.19(\text{ORIE}) + 105.25(\text{ORIS}) + 102.11(\text{LogR}) + 225.04(\overline{\theta}) + 412.73(\text{VENT})
\] (10)

Semi-log model for COS:

\[
\ln(\text{PRI}) = 7.857 + 0.016(\text{FLA}) + 0.019(\text{ORIN}) + 0.048(\text{ORIE}) + 0.035(\text{ORIS}) + 0.080(\text{LogR}) + 0.052(\overline{\theta}) + 0.122(\text{VENT})
\] (11)

It can be seen that positive coefficients have been generated for all the variables. This is judged to be reasonable because the less desired options were set as the base group. The four models have similar coefficients of determination \(r^2\), ranging between 0.464 and 0.56. Considering there are over 100 samples from both estates, the resultant \(r^2\) indicates a significant correlation to confirm that architectural and environmental attributes have a positive influence on the properties’ market price (Milton & Arnold, 1987).

The \(r^2\) for RA is 0.56 (linear model) and 0.546 (semi-log model), while that of COS is 0.5 (linear model) and 0.464 (semi-log model).
Correlations tend to be stronger for a smaller number of samples (Hill & Lewicki, 2006). While the site scale of COS is much bigger than that of RA, the correlation is stronger in the RA case.

Willingness to pay (WTP) of various attributes

Coefficients of the independent variables in the two linear models (Equations (8) and (10)) indicate how much the PRI is expected to increase when an independent variable increases by one, holding all other independent variables constant. These enable determination of the marginal WTP for each attribute (Table 3).

Based on the range and mean marginal WTP of the studied attributes, their WTP (HKD/ft²) have been determined and ranked (Table 4).

Elasticity of substitution (ES) of various attributes

From the coefficients of the independent variables in the two semi-log models (Equations (9) and (11)), ES of the studied attributes in the two residential estates are compared and ranked in Table 5.

Influence of different attributes on WTP and ES

It is no surprise to see in Tables 3 and 4 that WTP and ES share the same ranking for different attributes. Between RA and COS, WTP and ES of RA for different attributes are in general higher than of COS, excepting FLA and VENT.

The higher WTP and ES for RA can be explained by the snob effect in economics, which refers to the situation where the higher household income group is willing to pay more for distinct elements (Uzgoren & Guney, 2012). RA, according to most property agencies in Hong Kong, is a luxury estate with an average market price of HK$5251/ft² while COS with an average market price of HK$3146/ft² is classified as only a self-contained housing estate.

The smaller WTP and ES for FLA and VENT of RA as compared to COS can be explained by the scarcity principle in economics which states that an attribute’s relative price increases more upon its relatively low supply (Lynn, 1991). The supply of different FLA and VENT in RA and COS is compared in Table 6, illustrating that large area (FLA) and cross-ventilated (VENT) units are widely available in RA, but not in COS.

Among the attributes, WTP and ES are the highest for LogR of RA (13.3%). This is attributed to the fact that RA is constructed along a

Table 3
Marginal WTP of the studied attributes (HK$/unit change of variable).

| Attributes               | Independent Variable | Unit    | RA  | COS |
|--------------------------|----------------------|---------|-----|-----|
| Architectural Floor area of residential unit | FLA | Square foot | 0.008 | 0.02 |
| Orientation of living room window | North ORI | — | 34.56 | 55.7 |
| East ORI | — | 451.69 | 145.19 |
| South ORI | — | 392.87 | 105.25 |
| Mean ORI | — | 293.04 | 102.05 |
| Environmental Traffic-induced noise and air quality | LogR | Meter | 359.47 | 152.11 |
| Daylight performance and view obstruction | ð | Radian | 523.03 | 225.04 |
| Natural ventilation performance | VENT | — | 287.01 | 412.73 |

Table 4
Range of WTP (HKD/ft²) of the studied attributes.

| Independent Variable | Unit | RA Value | WTP | Rank | COS Value | WTP | Rank |
|----------------------|------|----------|-----|------|-----------|-----|------|
| Architectural FLA    | Square foot | 715 | 5.7 | 5 | 389 | 7.8 | 5 |
| ORI                  | 1623 | 13.0 | 1018 | 20.4 |
| North (1167) ORI     | (9.3) | (469) | (9.4) |
| South ORI            | 34.6 | — | 1 | 55.7 | — |
| LogR                 | 392.9 | — | 1 | 105.3 | — |
| Overall              | 293 | 3 | 1 | 102.1 | 4 |
| Environmental LogR   | Meter | 1.645 | 591.3 | 1 | 0.992 | 150.9 | 2 |
| ð                     | 2.214 | 795.9 | 2 | 2.441 | 371.3 |
| VENT                 | 0.6136 | 320.9 | 2 | 0.1644 | 37.0 | 3 |
| Overall              | 1.5708 | 821.6 | 1 | 1.5708 | 353.5 |
| Environmental LogR   | Meter | 0.6136 | 320.9 | 2 | 0.1644 | 37.0 | 3 |
| ð                     | 1.5708 | 821.6 | 1 | 1.5708 | 353.5 |
| VENT                 | 0.6136 | 320.9 | 2 | 0.1644 | 37.0 | 3 |
| Overall              | 1199.2 | 600.6 | 1 | 1137.5 | (886.8 – 28.2%) |

Remarks

a Mean values in parenthesis.

b % relative to the average property market price (5251 for RA; 3146 for COS (HK$/ft²)).
busy road where traffic-induced noise and air pollution problems are considered the two most concerned environmental attributes.

It is worth noting that the overall WTP (in HK$/ft²) and ES for environmental attributes (886.8 (COS) and 1672.7 (RA) for WTP and 3.4—13.3% for ES) are much higher than the architectural attributes (111.5 (COS) and 302.3 (FA) for WTP and 0.6—5.5% for ES). The big difference (2.4—7.9 times) is consistent with the earlier discussions (Section 2) that the environmental attributes are often perceived as affecting people's well-being and health condition, which are issues that deserve a higher value; as opposed to better architectural conditions which are only something nice to have.

Conclusion

In order to identify the impact of different architectural and environmental attributes on prices of residential properties in Hong Kong, price models of linear and semi-log forms were developed by the hedonic price method. The models relate market prices of residential units with five independent variables. The independent variables include two parameters for reflecting the architectural characteristics of a residential unit, floor area (FLA) and orientation of the living room windows (ORI). While the other three independent variables are the simple indicators identified to represent the environmental characteristics of residential units. They are the distance from road (LogR), mean angle of unobstructed sky (θ) and existence of cross ventilation (VENT).

Coefficients of the linear price model of the two studied estates enable the calculation of WTP of various architectural and environmental attributes. These are HK$302.3/ft² and HK$886.8/ft² for RA and HK$1672.7/ft² and HK$1115.5/ft² for COS. They correspond to 5.8% and 31.9% of RA's average market price and 3.5% and 28.2% of COS's average market price. The results reveal that environmental attributes command higher WTP than architectural attributes.

Coefficients of the semi-log price model of the two studied estates show that ES for good environmental quality contributes 3.4—13.3% to the property price, as compared to 0.6—5.5% for architectural quality.

The WTP and ES values determined in this study indicate that homebuyers valued the environmental attributes much higher than the architectural attributes. Such information as well as the numerical values does not appear to have been covered in extant literature. They are expected to be useful in encouraging building developers to construct for better environmental quality and for the homebuyers in making home purchase decisions.

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