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On the Stability of the Implicit Prices of Housing Attributes: A Dynamic Theory and Some Evidence

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Given the dramatic fluctuations in aggregate housing prices, this paper attempts to examine whether the implicit prices of different housing attributes are "stable." Theoretically, this paper provides perhaps the first dynamic, general equilibrium model in which housing attributes' implicit prices fluctuate. Empirically, this paper models the time paths of different implicit prices as auto-regressive processes by employing a hedonic pricing model on a large set of housing transaction data over a relatively long period of time. An endogenous structural break test is then performed. Except for a few attributes, structural breaks are not detected. Directions for future research are discussed.

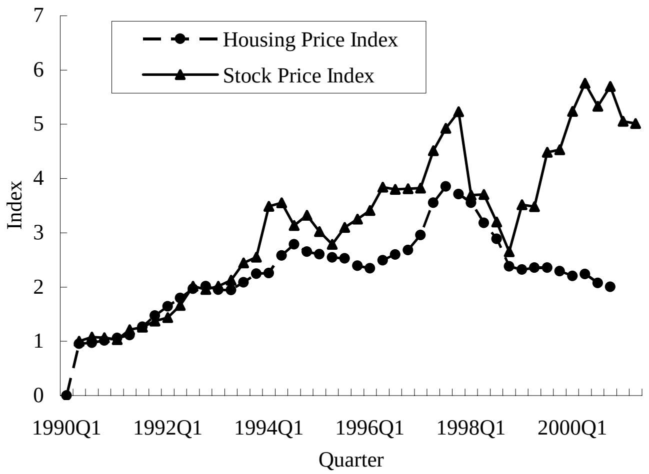
Keywords

hedonic pricing; structural break; evolution of valuation; housing attributes

Introduction

Aggregate housing prices are well known to exhibit dramatic fluctuations over time. One obvious example is the real estate markets in Asia during the financial crisis in 1997-1998. In Korea, housing prices dropped by 12.6 percent and the construction of new houses decreased by 48.7 percent, in 1998.[1] In Bangkok, the vacancy rate reached 50 percent in the downtown residential property.[2] In Hong Kong, the price of residential property dropped by one half and the price of commercial property (office and industry) dropped even more.[3] Figure 1 provides a visualization of this phenomenon. Mera and Renaud (2000) report that dramatic decline in property prices and occupancy rates were common phenomena in other Asian markets.

Figure 1: Hong Kong Housing and Stock Price Index: 1990-2001



It is now clear that the financial crisis depressed the overall property price. But a less trivial question is: Did the financial crisis also change the relative pricing of different properties?[4] In other words, how "stable" are the implicit prices of different housing attributes in the midst of a crisis? Since housing constitutes a significant portion of a typical household's wealth, a drop in property price levels can produce a very large negative wealth effect, which may cause the demand for some housing attributes to decline relative to others.

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[1] See Kim (2000).
[2] See Renaud (2000).
[3] See Rating and Valuation Department, *Hong Kong Property Review* (various issues) and Chow et al. (2002). See also Leung, Leong and Chan (2002), Mera and Renaud (2000)
[4] Recently, there have been many contributions on the wealth effect of the housing market. Among others, see Case, Quigley and Shiller (2005), Edelstein and Lum (2004), and Bostic, Gabriel and Painter (2005).

For instance, due to the negative wealth effect of the financial crisis, the demand for certain “luxurious attributes” was likely to drop. If a housing unit is interpreted as a collection of housing attributes, then the residential housing price of luxurious housing would decline “more than average.” This paper takes this hypothesis seriously and intends to verify it by tracking the market valuation, or the implicit prices,[5] of different housing attributes over a period of time, with significant wealth movements. In fact, some authors, such as Edmonds (1985) and Meese and Wallace (1997), have noticed that the market price of housing attributes needs not be constant over time. Thus, drawing a conclusion from merely comparing the implicit prices of housing attributes at some particular point in time before the crisis and at some other particular point in time thereafter may be misleading. A better approach is to model the fluctuations of the implicit prices of attributes as a function of both “normal” changes in macroeconomic factors and the possible dramatic change due to the financial crisis. Technically speaking, this can be done by describing the prices of housing attributes as some stochastic processes so that we can check the “stability” of the implicit prices of the housing attributes by an endogenous “structural break” test.

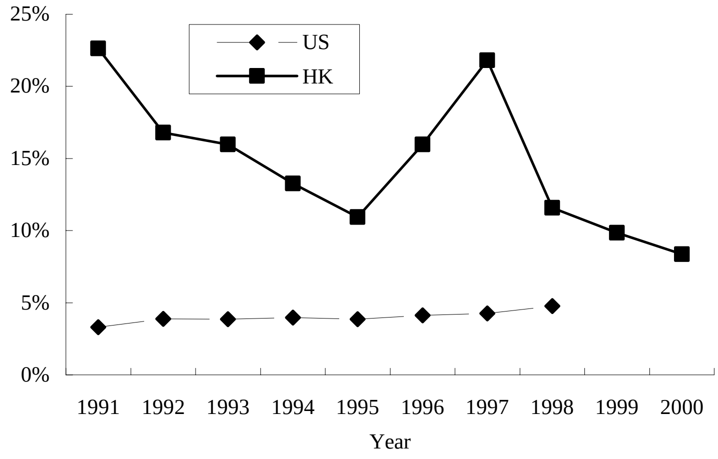
Given these complications, this paper will make several contributions to investigate the stability of the implicit prices of housing attributes. First, we will provide perhaps the first dynamic, general equilibrium model on the movement of housing attributes’ implicit prices. The model will illustrate the existence of “normal” fluctuations of implicit price movements over the business cycles. Second, empirical hedonic pricing equations will be run for successive periods of time. In each period, the point estimate of the coefficient of each housing attribute will be interpreted as the implicit price of that attribute. This procedure of period-by-period regression allows for the coefficients to be time-varying, and minimizes the risk of time-aggregation bias, which has long been recognized in the literature.[6] Third, as the implicit prices are expected to fluctuate with the cyclical movement of the economy, a structural break test will be conducted. If there is no sign of structural change in the implicit prices of housing attributes after the Asian financial crisis, it is very likely that, though the implicit prices fluctuate over time, they are “stable” processes. To minimize the potential bias from subjective judgment, this paper adopts recently-developed tests to determine the break time endogenously (for instance, see Andrews, 1993).

The empirical analysis of this paper is based on a large sample of property transactions in Hong Kong (more than 220,000 transactions). We split the sample into 54 quarterly sub-samples according to the time of transaction,

[5] See Rosen (1974). The terms “market evaluation” and “implicit price” will be used interchangeably here.
[6] See, for instance, Christiano and Eichenbaum (1987) and Christiano, Eichenbaum and Marshall (1991).

running from the first quarter of 1992 to the second quarter of 2005. There are several reasons why the Hong Kong market is a quality choice for this research. First, it was severely suppressed by a financial crisis that began around the fourth quarter of 1997.[7] Second, this paper mainly focuses on apartment units, and, hence, the concern for "option value" of re-development is safely ruled out. Third, this market is very "active," especially before the financial crisis. There are more than 1,500 transactions in each quarter during most of the time, with a total of more than 220,000 transactions in the sample. The diversity of prices and the transacted units enables the market to price the housing units efficiently. In figure 2, the ratio of the total number of transactions of residential property relative to the total amount of stock in Hong Kong is plotted against time. It is clear that, in comparison with the United States, the Hong Kong market is indeed more "active." (The USA data are extracted from Simmons (2000) and the HK data are from Rating and Valuation Department (2004).)

Figure 2: The degree of activeness of the market



There are several other merits of using the Hong Kong housing market data. In contrast to the U.S., there is no local public finance arrangement in Hong Kong. The tax system of the Hong Kong market is simple. In contrast to some other Asian countries, there is no barrier to capital flow. The exchange rate of the domestic currency, in terms of the U.S. dollar, is fixed throughout the

[7] For instance, see Devereux (2003) and the references therein.

entire sampling period, and thus facilitates the comparison and the participation of foreign investors.[8]

Needless to say, this paper builds on many insights of the previous literature. However, the literature on "hedonic pricing in real estate" is too large to be reviewed here. Thus, we can only briefly review a few of the contributions. Interested readers are referred to Malpezzi (2002), among others, for a comprehensive literature review.[9] There is a long history of researchers applying the hedonic pricing equation on the housing market, such as Straszheim (1974) and Witte, Sumka and Erekson (1979).[10] The values of many "housing attributes," such as flood insurance, golf courses, neighborhood churches, quietness, sea-view, traffic, etc., have all been studied.[11] Some literature has also found that hedonic estimation is affected by the quality of public schools, the age of residents, government regulation, market segmentation, search behavior, and the time-varying nature of implicit prices.[12]

The organization of this paper is as follows. The next section presents a simple equilibrium model, which generates time-varying implicit prices of different housing attributes. We will then provide a description of the data used, followed by a discussion of the methodology. After this, the empirical findings and interpretations of these findings are presented. A conclusion is given in the final section.

A Simple Equilibrium Model

To demonstrate the idea that the implicit prices of housing attributes will fluctuate over time, this section will build a dynamic, general equilibrium model. The model is an extension of the theoretical works of Kwong and Leung (2000) and Kan, Kwong and Leung (2004), which follow the general equilibrium asset pricing model of Lucas (1978). Therefore, the description

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[8] Hong Kong does not have the type of "zoning" policy such that local residents can vote to decide the minimum size of the housing unit in the district. Among others, Pogodzinski and Sass (1991) have shown that this type of zoning policy can have implications on the housing price. In terms of Hong Kong taxation, capital gains tax has never been imposed, and the tax rate on income is essentially flat, and maintained at a low level.

[9] Among others, see also Halvorsen and Pollakowski (1981), McMillan, Reid and Gillen (1980), Wallace (1996), Wilhelmsson (2002).

[10] For a history of hedonic study, see also Colwell and Dilmore (1999).

[11] For an estimation of the implicit prices of different attributes, see Do, Wilbur and Short (1994), Do and Grudnitski (1995), Hughes and Sirmans (1992), Mok, Chan and Cho (1995), Shilling, Sirmans and Benjamin (1989), among others.

[12] For the possible interaction between implicit prices and the other factors, see Brasington (1999), Dale-Johnson (1982), Do and Grudnitski (1997), Edmonds (1985), Goodman and Kawai (1982), Hughes and Sirmans (1992), and Meese and Wallace (2003). See Cheng (2002) for more discussion.

here is brief.[13] In the model, time is discrete and the horizon is infinite. The population is constant and is normalized to unity. There are two goods – a non-durable consumption good and durable residential property. The total stock of residential property is assumed to be fixed in supply. Our analysis will focus on the representative agent of the economy.

At time t (t = 0,1,2,...), the representative agent maximizes the expected value of lifetime utility

$$E_t \sum_{s=t}^{\infty} \beta^s (\ln C_s + \omega \ln H_s) , \tag{1}$$

which is the expectation of a discounted sum of the periodic utility ($\ln C_s + \omega \ln H_s$),[14] where β ($0 < \beta < 1$) is the discount factor, ω (> 0) is the preference parameter which governs the substitution between consumption and residential property, C_s is the amount of consumption in period s, and H_s is the service flow generated from residential property in period s (s = t, t+1, t+2,...). Essentially, we are assuming that the preference for residential stock and consumption of non-durables is log-separable. This is a strong assumption that enables us to obtain closed-form solutions and sharp predictions.[15] We assume that the service flow of property depends on the amount of different attributes embedded in the housing stock, following a Cobb-Douglas functional form,

$$H_t = \Pi_{i=1}^{n} (h_{it} - \bar{h}_i)^{\alpha_i} + H_t^0 , \tag{2}$$

where h_{it} is the amount of attribute i embedded in the housing stock at time t, $\bar{h}_i$ is attribute-specific parameter for attribute i, $0 < \alpha_i < 1$, $\sum_{i=1}^{n} \alpha_i = 1$, and H_t^0 is the amount of finished housing directly purchased from the market at time t. We assume that $(h_{it} - \bar{h}_i) > 0$ for each attribute i and each period t. As shown by Kongsamunt, Rebelo and Xie (2001), attribute i has an income elasticity smaller/equal to/larger than unity, if $\bar{h}_i$ is positive/zero/negative.

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[13] See also Leung (1999, 2001, 2006).

[14] There are many ways to justify placing the stock of residential property in the utility function, and the following is one of them. Let the utility function depend on the service flows d_t from the residential capital, and the production of service flows be linear in the amount of residential capital occupied, $d_t = d * h_t$, 0<d. Then, the reduced form of the utility will depend on the stock of the residential capital.

[15] The virtue of log-utility function is that it makes the substitution effect and wealth effect cancel each other out in the computations and thus simplify the algebra significantly. The assumption of separability between durable and non-durable consumption has some empirical support. For instance, see Anderson (1991).

Following the tradition of economics, when the income elasticity is smaller (*larger*) than unity, the attribute i is considered a necessary (*luxury*) good.

To focus on the pricing issue, we consider the case where the residential housing has no impact on goods production. In particular, we assume that the agent invests all her savings in one financial asset, and the asset returns R_t follow a stationary stochastic process, with bounded first and second moments, i.e., $0 < R_t < M < \infty$ for some constant M, $\forall$t, and

$$E(R_t) = \mu_R, \quad 0 < \mu_R < \infty, \quad Var(R_t) < \infty . \tag{3}$$

The agent can buy/sell residential property at unit price P_t^h in the market. To guarantee time-consistency in the stochastic dynamic optimization problem, dynamic programming technique is used and the Bellman equation is formulated as follows:

$$V(\{h_{it}\}_{i=1}^n, A_t) = \max_{c_t, h_{t+1, ft+1}} \ln C_t + \omega \ln(H_t) + \beta E_t V(\{h_{i,t+1}\}_{i=1}^n, A_{t+1}) \tag{4}$$

s.t. (2), and

$$C_t + \sum_{i=1}^n P_{i,t}^h (h_{i,t+1} - h_{i,t}) + A_{t+1} + P_t^h (H_{t+1}^0) \leq R_t A_t , \tag{5}$$

where A_t is the amount of financial asset holding at time t, E_t is the rational expectation operator, given time t information. This formulation implicitly assumes the ideal situation, where the agent can either purchase different housing attributes separately, or purchase some existing stock from the (second-hand) market. Obviously, this is a conceptual construction to enhance the mathematical derivation, similar to the state-contingent claim in the finance literature.

Let λ_{1t} and λ_{2t} represent the multiplier of the constraint (2) and (5), respectively. It is easy to see that the first order conditions are:

$$\lambda_{2t} = 1 / C_t , \tag{6}$$

$$\lambda_{1t} = \omega / (H_t) , \tag{7}$$

$$\lambda_{1t} = P_{t+1}^h \lambda_{2t} , \tag{8}$$

$$\lambda_{2t} P_{i,t}^h = \beta E_t \{(\omega \alpha_i / (h_{i,t+1} - \bar{h}_i)) + \lambda_{2,t+1} P_{i,t+1}^h\}, \forall_i , \tag{9}$$

and $\lambda_{2t} = \beta E_t\{\lambda_{2,t+1} R_{t+1}\}$. (10)

Assuming that there is no eternal bubble, i.e.,

$$\lim_{s\to\infty} \beta^s E_t\{\lambda_{2t+s} P^h_{i,t+s}\} = 0, \quad \lim_{s\to\infty} \beta^s E_t\{\lambda_{jt+s}\} = 0, \tag{11}$$

j = 1,2, it is possible to derive the "asset-pricing equations" from (9) for each housing attribute:

$$P^h_{i,t+s} = (\omega\alpha_i / \lambda_{2t})\sum_{s=t+1}^{\infty} E_t(\beta^{s-t}(h_{i,s} - \bar{h}_i)^{-1}), \ \ \forall_i . \tag{12}$$

To solve the model, we need to impose some equilibrium conditions. Following Lucas (1978), and for simplicity, we assume that the stock of housing attributes are fixed at h_i, ∀ i (the results are qualitatively similar even if we allow for endogenous supply of housing attributes).[16] In equilibrium, the stock owned by the representative agent must be equal to the per capita counterpart, and, hence, the equilibrium condition for the property market is simply:

$$h_{it} = h_i, \ \forall_i, \ \forall_t . \tag{13}$$

Consequently, the equilibrium condition for the goods market is

$$C_t + A_{t+1} = R_t A_t , \tag{14}$$

which means that income not consumed will be saved, and earn at a rate of return R_{t+1} in the following period. Following Lucas (1978), we impose the condition that the net trade of the representative agent is zero at the equilibrium,

$$H^0_t = 0, \ \forall_t . \tag{15}$$

Again, following Lucas (1978), Kwong and Leung (2000), and Kan, Kwong and Leung (2004), we conjecture that the consumption is a fixed fraction of the total output,

$$C_t = \eta R_t A_t , \tag{16}$$

[16] For instance, see Kwong and Leung (2000), Kan, Kwong and Leung (2004).

which means that $A_{t+1}=(1-\eta)R_tA_t$. Equipped with the equilibrium conditions and the conjecture, it is easy to verify that (10) can be reduced to

$$\eta = 1-\beta \, , \tag{17}$$

which shows that η is indeed a constant, and (12) can be simplified to

$$P^h_{i,t} = \varphi^h_i R_t A_t \, , \tag{18}$$

or $\ln(P^h_t) = \alpha_t + \varphi_i$, (19)

where $\varphi^h_i = (\omega\beta\alpha_i /(h_i - \bar{h}_i)), a_t = \ln(R_t A_t), \varphi_i = \ln(\varphi^h_i)$. This means that, in addition to a number of parameters of preference and housing-service production, the price for each housing attribute should depend on the asset return, as well as on the amount of asset holding (or wealth) during that period. It also shows that if there is a significant drop in asset return, say during a financial crisis, then R_tA_t will decrease and, hence, the price for the housing attributes. In addition, the "implicit prices" of different attributes, $P^h_{i,t}$, may react to the asset return change differently, depending on the preference parameter φ^h_i, which, in turn, depends on $\alpha_i, h_i, \bar{h}_i$.

Now, we need to relate the market price for each housing attribute to the housing price of the second-hand market. Combining equations (6) to (8), we get

$$P^h_t = (\omega\beta / H) R_t A_t \, , \tag{20}$$

where

$$H = \Pi^n_{i=1}(h_i - \bar{h}_i)^{\alpha_i} \, , \tag{21}$$

by (13) and (15). Now combining (18), (20) and (21), we get

$$P^h_t = \Pi^n_{i=1}\left(\frac{P^h_{i,t}}{\alpha_i}\right)^{\alpha_i} = (\omega\beta R_t A_t)\bullet \Pi^n_{i=1}(h_i - \bar{h}_i)^{-\alpha_i} \, , \tag{22}$$

or $\ln(P^h_t) = \alpha_0 + \alpha_t + \sum_i \alpha_i \ln(h_i - \bar{h}_i)$, (23)

where $\alpha_0 = \ln(\omega\beta)$. In other words, this means that, in addition to parameters, the second-hand housing price depends on the asset return, as well as on the amount of asset holding (or wealth) during that period, the amount of different housing attributes. This justifies our approach to regress the second-hand housing price against the housing attributes.

This model has some merits. It is simple and the results are transparent. The price of each housing attribute is endogenously derived, even taking into account the general equilibrium effect. However, this model also has some limitations. First, it assumes all attributes are divisible, while in a typical hedonic equation, we would include discrete variables, including dummy variables taking either zero or unity. And since log(zero) is mathematically undefined, the log-version of equation (22) cannot be implemented directly. Second, the model assumes separability between nondurable consumption and housing. In reality, the utility functional form may be more complicated, and some equations would need to be refined. As a first step, this paper would employ a simple hedonic pricing model, which can be interpreted as a simple Taylor expansion of the potentially more-complicated model. In spite of its simplicity, the linear hedonic pricing model does receive some support from previous research.[17] More discussion on this will follow. Now we turn to the description of the data set used in this paper.

Date Description and Methodology

The housing data used in this paper are mainly composed by a private agent, Economic Property Research Center (EPRC).[18] The total number of transactions in Hong Kong from 1992 to 2005 is more than 1 million, and an analysis of such a large sample is difficult. More importantly, that "full sample" will consist of the trading of detached houses, apartment units, and century-old village houses sold to developers for re-development with modern, artificial-intelligence units. With such a great degree of heterogeneity, the attention of this research is restricted to the "most frequently traded list" of estates.[19] There are, in total, more than 220,000 transactions within the

[17] For instance, see Cropper, Deck and McConnell (1988). Recently, Meese and Wallace (2003) show that traditional approach and the modern simultaneous estimator approach generate very similar empirical results.

[18] EPRC traces all sales and purchase records for all individual property since the 1990s. In Hong Kong, all transactions need to be reported to the Land Registry of the Hong Kong government. EPRC, a subsidiary of the Hong Kong Economic Times, purchases all those individual files from the Land Registry and then reorganizes them and resells them to commercial and educational users. The right to use that data set is sold to the author under the agreement that the data will not be used for commercial purposes. However, some property information (e.g., ancillary facilities) of individual buildings is not available in that data set. That information was supplemented by the websites of several real estate agents, such as Centaline and Century 21.

[19] An "estate" in this paper is similar to a "housing development" in the U.S., i.e., a group of buildings built in the same neighborhood, at about the same time, usually by a single developer. In Hong Kong, the population of some large estates is very significant. For instance, Taikoo Shing has 61 buildings, and each is more than 20 stories high. In Hong Kong, there are some private apartment units subsidized by the government, and their trading is subject to certain government regulations. They are excluded from this study.

sampling period. Macroeconomic data are extracted from different issues of the Annual Digest of Statistics, published by the Hong Kong government.

As mentioned in the introduction, the literature on the hedonic pricing approach, applied to housing, is large. This paper, however, differentiates itself from the previous efforts by explicitly allowing for the market valuation of housing attributes to fluctuate over time[20], and examines whether the "pattern" of the fluctuation displays any change after a financial crisis.[21] Specifically, for each quarter, a semi-log cross-sectional hedonic pricing equation is estimated in the following form:

$$\ln P = \beta_o + \beta_1 S + \beta_2 L + \beta_3 N + \varepsilon, \qquad (24)$$

where P represents property prices, **L** represents location traits (such as which district the building belongs to), **S** represents structural traits (such as the floor level of the apartment unit and the age of the building), **N** represents neighborhood traits (such as the proximity to railway stations and the proximity to water), ε is the error term in regression, and β_i, $i = 0,1,2,3$, are the vector of coefficients obtained in each period t. The regression is semi-log, and we follow the convention to interpret the point estimate of β as the (log) implicit price, or market valuation, of different housing attributes at period t. Although the values of β are expected to display some level of fluctuation "normally" (for instance, due to seasonal cycles or business cycles), a financial crisis, which could significantly change the relative demand for different attributes, could lead to a long-lasting and significant change in the values of β.[22]

Table 1 shows the list of variables used in the hedonic pricing equation. In the current data set, the numbers of bedrooms and bathrooms are not available, as occupiers can re-model the housing units freely, as long as structural safety is not affected. Since most housing units in the sample are apartments rather than detached houses, "floor" is included as one of the independent variables for these units. Usually, apartment units at higher floors would have more open (unobstructed) views. For village-type detached houses, a dummy "village" is

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[20] The econometrics techniques used in this paper are widely discussed in the literature. Among others, see Campos, Ericsson and Hendry (1996), Chow (1960), Greene (1997), Quandt (1960), Raj (1992).

[21] The sample size is also larger than some previous research. For instance, Mok, Chan and Cho (1995) base their analysis on about 1,100 transaction records from a particular estate in a particular year. However, different estates in Hong Kong might display very different patterns. For instance, Leung, Lau and Leong (2002) find that while *most* estates display a *positive* and statistically significant relationship between the property price and trading volume, a *few* estates display a *negative* and statistically significant relationship. Therefore, it is important to study at the estate level, for a more robust analysis.

[22] The adjustment of the housing stock is slow, and each housing unit is potentially on the market. Therefore, it seems reasonable to assume that if the demand changes, most of the adjustment will occur through the price.

used to capture their special characteristics. Some previous research indicates that Chinese people may have some superstitious beliefs affecting their housing market behavior.[23] To entertain this potential demand, "lucky" is included to indicate whether a housing unit is associated with a lucky floor number or not. In the current sample, clubhouse and swimming pool are almost perfectly collinear, and therefore only "swim_pool" is included to represent both effects. "Age" of the housing unit is used as a proxy for potential maintenance costs embedded in the housing unit. In Hong Kong, the subway and the train are called "MTR" and "KCR," respectively.[24] Being geographically close to these stations may mean convenience, but, also, a noisy environment. Other variables include "water", which captures the effect of being geographically close to seas, and "hill", which represents housing located in the luxurious hill areas of Hong Kong (e.g., Mid-levels and the Peak). Geographically, Hong Kong is traditionally divided into three parts: Hong Kong Island, Kowloon Peninsula and the New Territories. Location variables, namely "HK" and "KL", are used for this rough geographical division. Table 2 provides the summary statistics of the attributes.

Table 1: List of variables

Variable	Definition
Dependent:	
ln(Price)	Log selling price of a housing unit (in HK$million)
Independent:	
Structural trait:	
Age	Age of the housing unit (in years)
Age^2	Square of age (to capture any non-linear effect)
Floor	Floor level of the housing unit
Floor^2	Square of floor level (to capture any non-linear effect)
Area	Floor area of the housing unit (in sq.ft.)
Area^2	Square of floor area (to capture any non-linear effect)
Lucky	1 if the floor level is 8,18,28 and 38; 0 otherwise
Village	1 if the housing unit is a village-type detached house; 0 otherwise
Swim_pool	1 if swimming pool is available within the estate; ; 0 otherwise

[23] For instance, see Woo and Kwok (1994) and Chau, Ma and Ho (2001).
[24] KCR developed several lines during our sampling period, which include West Rail ("KCR_W"), East Rail ("KCR_E"), and Ma On Shan Rail ("KCR_MOS").

Table 1: List of variables (Continued)

Neighborhood trait:	
MTR	1 if MTR is available within 0-500 meters; 0 otherwise
KCR_E	1 if KCR East Rail is available within 0-500 meters; 0 otherwise
KCR_W	1 if KCR West Rail is available within 0-500 meters; 0 otherwise
KCR_MOS	1 if KCR Ma On Shan Rail is available within 0-500 meters; 0 otherwise
Water	1 if distance from water within 0-500 meters; 0 otherwise
Hill	1 if distance from hills within 0-500 meters; 0 otherwise
Location trait:	
HK	1 if the housing unit is located on Hong Kong Island; 0 otherwise
KL	1 if the housing unit is located on Kowloon peninsula; 0 otherwise

Table 2: Descriptive statistics

Variable	Mean	Maximum	Minimum	Std. Dev.
Continuous variables				
Price (million)	3.29	63.97	0.01	2.52
Age	9.71	37.00	0.00	7.09
Floor	10.27	45.00	1.00	24.85
Area	618.09	2668.00	212.00	240.28
Dummy variables:				
Lucky	9.0%			
Village	4.2%			
Swim_pool	93.8%			
MTR	38.9%			
KCR_E	6.6%			
KCR_W	1.0%			
KCR_MOS	0.3%			
Water	40.9%			
Hill	3.4%			
HK	26.8%			
KL	26.5%			
Sample size	221,618			

Notice that the information of buyers' income or wealth is not included in the regression. This is because this information is missing, even in the official record. We can only acknowledge this limitation and proceed nevertheless.[25]

To examine the "stability" of these implicit prices, we consider the Asian financial crisis in 1997-1998 to be a natural experiment. Formally, we evaluate whether structural changes in the values of β occur in the sampling period. A structural change is a statement concerning parameters in a model. Following Hansen (2001), we model the implicit prices of housing attributes in the simplest dynamic model (i.e., first-order autoregression with an intercept term), and define "structural break" in this context:

$$\beta_{i\,t} = \alpha + \rho\beta_{i\,t-1} + e_{\,t} \quad . \tag{25}$$

To our knowledge, our study seems to be the first to explicitly model the implicit prices as autoregression (AR) processes and examine their "structural stability."

The structural break test employed here is developed by Andrews (1993),[26] which does not rely on the discretion of the researcher as to when the "break" may have occurred. Roughly speaking, it proposes to take the largest Chow statistic over all candidate break dates.

While the details of these structural break tests are technically very involved, the idea is simple and can be explained in simple terms. Consider a time series {x(t)}, which may be a member of the vector { $\beta_{i\,t}$ }. We only consider the scenario that there can be, at most, one break during the sampling period, as the length of the time series is relatively short. The benchmark is to assume there is no break and then let x(t) regress on a constant and its past observation. Then, we assume a break occurs at certain date T, and split the series into two parts, and then regress the two parts separately. Under this assumption, we can explain the series to a certain extent. Since the data series is finite, the computer can repeat the same procedure for another hypothetical date of structural break. In fact, the computer program can check if a break occurs at any date, within the sampling period.[27] After finding the largest values among a sequence of Lagrange Multiplier (LM) test statistics, we can determine

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[25] In the literature, the effect of adding income and wealth variables is controversial. For instance, while Song (1995) and Cheshire and Sheppard (1998) claim that the contribution is marginal, Harding, Rosenthal and Sirmans (2003) find that it is important.

[26] It has been used in some applied works, also. For instance, Pastor and Stambaugh (2000) apply these tests in the stock market.

[27] Actually, we do not consider literally "all" possible break dates. We cannot consider break dates too close to the beginning or end of the sample, as there are not enough observations to estimate the parameters in each sub-sample (i.e., the test statistics might not be powerful enough). The conventional solution is to consider the break dates in the interior proportion of the sample. In the analysis presented here, we adopt 15 percent trimming at both "ends" of the sample.

whether a break does occur, with the critical values provided by Andrews (1993). The procedures may sound complicated, but it is feasible to implement with a computer program.

This analysis is particularly important for this project because the financial crisis, which occurred in the winter 1997, might not instantaneously induce a change of demand of certain housing attributes. For instance, the investors may have interpreted that the crisis was only a temporary phenomenon initially. After some period of time, however, they realized the severity and may have decided to change their investment strategies. Alternatively, some investors might have been “locked-in” by some contracts and were unable to adjust their portfolios in the short run. But, the investors would obtain more accurate estimates of the risk and return of different portfolio allocations over time. How long the adjustment in expectation took, however, may have differed across individuals, and, more importantly, it is not directly observable. Therefore, it is important that the researcher use some objective and mechanical procedures (such as the endogenous structural break test we adopt here), rather than any subjective judgment, to decide whether certain structural breaks occur during the sample period.

Empirical Results

Simple (cross-sectional) OLS results

The first set of results comes from a series of cross-sectional hedonic price regressions. In each period or quarter, about 18 implicit prices are estimated, and there are 54 periods in total. Tables 3a and 3b provide a summary of the results.

Table 3a: Signs and significance of implicit prices of the housing attributes

Implicit Prices	Positively Significant at 0.05 Level	Negatively Significant at 0.05 Level	Insignificant
Age	**88.89%**	1.85%	9.26%
Age^2	0.00%	**100.00%**	0.00%
Floor	**100.00%**	0.00%	0.00%
Floor^2	0.00%	**98.15%**	1.85%
Area	**100.00%**	0.00%	0.00%
Area^2	0.00%	**100.00%**	0.00%
Lucky	3.70%	1.85%	**94.44%**
Village	9.26%	**75.93%**	14.81%
Swim_pool	**79.63%**	0.00%	20.37%
MTR	**75.93%**	0.00%	24.07%
KCR_E	**98.15%**	0.00%	1.85%
KCR_W	0.00%	**66.67%**	33.33%
KCR_MOS	**100.00%**	0.00%	0.00%
Water	44.44%	5.56%	**50.00%**
Hill	**100.00%**	0.00%	0.00%
HK	**100.00%**	0.00%	0.00%
KL	**100.00%**	0.00%	0.00%
Constant	0.00%	**100.00%**	0.00%

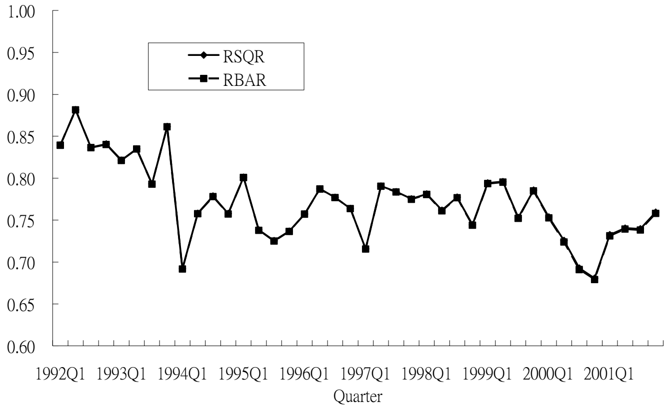
Table 3b: Summary statistics of the implicit prices of housing attributes

Implicit Prices	Mean	Standard Deviation	Minimum	Maximum
Age	0.0182	0.0104	-0.0045	0.0374
Age^2	-0.0011	0.0005	-0.0024	-0.0004
Floor	0.0108	0.0022	0.0054	0.0185
Floor^2	-0.0002	0.0001	-0.0005	8.8E-06
Area	0.0024	0.0002	0.0016	0.0028
Area^2	-5.2E-07	7.6E-08	-6.7E-07	-2.1E-07
Lucky	0.0064	0.0193	-0.0973	0.0622
Village	-0.1483	0.1456	-0.3879	0.1162
Swim_pool	0.0853	0.0481	-0.0155	0.1740
MTR	0.0517	0.0297	-0.0210	0.1217
KCR_E	0.1605	0.0660	0.0528	0.4252
KCR_W	-0.1154	0.0769	-0.1757	-0.0117
KCR_MOS	0.3472	0.0412	0.3181	0.3764
Water	0.0277	0.0373	-0.0254	0.1361
Hill	0.3234	0.0789	0.1831	0.5320
HK	0.3411	0.0779	0.1830	0.5080
KL	0.2385	0.0475	0.1438	0.3541
Constant	-0.7110	0.3412	-1.4770	-0.0589
R^2	0.8109	0.0616	0.6340	0.8897
Adj. R^2	0.8099	0.0622	0.6310	0.8895

Notice that the implicit prices of most housing attributes show plausible and very consistent signs. The coefficient of "age-squared" is always negatively significant at the 5% level, while that of "age" is positive and mostly significant. These, together with their magnitudes, reflect that consumers prefer newer apartments, and such preference diminishes marginally. Similarly, the positive coefficients of "floor" and "area" and the negative coefficients of their square terms imply that consumers enjoy higher floor levels and larger apartment units with diminishing marginal utility. The implicit prices of "lucky" are usually insignificant, meaning that people might not be as superstitious as some researchers claim. The implicit prices of village-type detached houses are generally negative, probably because they are located in very remote areas. As expected, the coefficients of "swim_pool", "MTR", "KCR_E", "KCR_MOS", "HK", and "KL" are always positively significant at the 5% level. This reflects that apartment units with swimming pools (or clubhouses) in their estate, those close to the subway or train stations (except for West Rail), and those located near hills – and not in the New Territories – are priced higher. For "water", about half of its coefficients are positive and significant at the 5% level, but the other half is insignificant. This may be due to the fact that being close to water (mainly the sea) would lead to faster corrosion (of furniture, as well as electrical appliances) and mold problems, and, thus, the market puts a "mark-down" on that feature.

It should be noticed from table 3b that the mean of R^2 and adjusted R^2 are high. On average, this simple semi-log hedonic price equation explains about 81 % of the housing price variations. It is interesting to note that although there are political regime shifts and policy changes during the sampling period, the same simple structure is capable of explaining the variations of the housing prices of different housing units consistently, by the difference of their attributes. Table 3b also shows that there are significant movements in these implicit prices. Thus, it is reasonable to model the implicit prices as some stochastic processes, and ask whether they are related to changes in macroeconomic factors during the sampling period. This is precisely the focus of the following section.

Figure 3: R-squared and adjusted R-squared



Note: The R-square and adjusted R-square differ so little that it is virtually impossible to be distinguished. This gives us further confidence as to our choice of variables on the right hand side.

Structural break results

Before we conduct the "structural break" test, there are some technical issues to be resolved. A prerequisite for sensible regression is that all the variables are stationary; otherwise, a spurious regression will overstate the significance of all of the explanatory variables. To verify stationarity of both the dependent and independent variables in the regressions, this paper follows common practice, which is to apply the augmented Dickey-Fuller (ADF) test.[28] It turns out that only the implicit prices of "swim_pool", "area^2", and "CONSTANT" are non-stationary, and they will be filtered by first-differencing. To distinguish these variables, we put a " Δ " in front of the original symbols. The others are stationary and therefore no further filtering procedure is needed.

The test results on structural breaks for the 16 implicit prices [29] are summarized in table 4 and the critical values of the corresponding structural break tests have been calculated by Andrews (1993, table 1). Now, we will explain how that table will be used. Since each of the implicit prices of housing attributes are tested individually with a constant term and an autoregressive term (see Eq.(25)), the value of p under the null hypothesis is 2, if we jointly test for stability of the two parameters, while p is 1 if we test for the stability of either parameter. We consider all three cases (namely, "Constant", "AR(1)" and "All Coefficients"), as a structural break may affect only one or all of the model parameters, resulting in different implications. We will use a heteroskedasticity-robust version of the test. In the original paper ***of Andrew (1993)***, only the asymptotic critical values are provided. The p-values reported here were computed using the simulation approach proposed by Hansen (1997).

Table 4 shows that none of the p-values for the joint test of implicit prices ("All Coefficients") are smaller than 5%, indicating that, generally, no structural breaks occur in these series, although the tests on the persistence term alone ("AR(1)") indicate instability in "Area^2" and "Hill" at the 5% significance level, and the tests for the intercept term alone ("Constant") indicate instability in "Area^2", "Hill", and "MTR" at the 5% level. These may signal a permanent shift in the mean value of the time series through the relationship $E(\beta_{it}) = \alpha/(1-\rho)$. Since "Hill" represents housing located in the luxurious hill areas of Hong Kong, its structural break lends some support to the hypothesis that the crisis-induced negative wealth effect has caused the demand for luxurious housing attributes to decline relative to others. This test shows that the break did not occur immediately after the crisis in 1997, but was deferred until 2000-2001. This suggests that adjustment in expectation took time. However, other potentially "luxurious" variables (e.g., the possession of clubhouses and being close to water) do not show any instability. It seems safe to conclude that, overall, the implicit prices of different attributes display no clear structural change despite the fact that the aggregate housing price in the same sampling period exhibits very dramatic fluctuations (see Figure 4).

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[28] The details of the unit root tests are available upon request.
[29]The implicit prices for West Rail and Ma On Shan Railway are not tested because of the insufficient length of their data series.

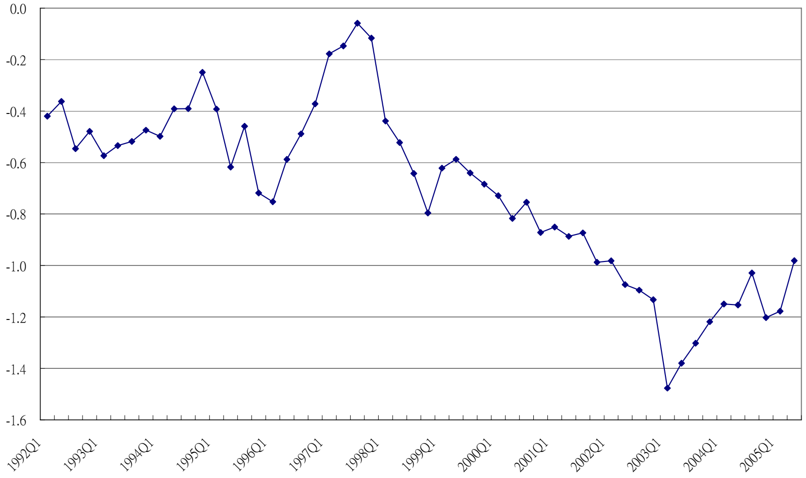
Table 4: Structural break test

Implicit Prices		Test Statistics	P-Value	Break Date
Age	Constant	3.133044	0.526833	1996:01
	AR(1)	2.386896	0.691181	1994:02
	All Coefficients	4.666509	0.613556	1994:03
Age^2	Constant	6.058272	0.156751	1996:01
	AR(1)	5.700675	0.18315	1996:02
	All Coefficients	7.384747	0.256727	1996:01
Floor	Constant	4.271288	0.335304	2001:03
	AR(1)	3.145217	0.5244	2001:03
	All Coefficients	10.06734	0.092155	2000:01
Floor^2	Constant	6.786569	0.113705	1994:03
	AR(1)	6.976033	0.104511	1994:03
	All Coefficients	9.382399	0.120964	2002:02
Area	Constant	4.049725	0.367078	1995:01
	AR(1)	4.006328	0.373598	1995:01
	All Coefficients	4.12881	0.704727	1995:03
Area^2	Constant	9.836283	**0.028429**	1995:01
	AR(1)	9.73915	**0.029736**	1995:01
	All Coefficients	9.842604	0.100825	1995:03
Lucky	Constant	5.143544	0.232686	2000:03
	AR(1)	3.648082	0.431293	2003:02
	All Coefficients	7.262375	0.268189	2003:02
Village	Constant	6.480812	0.130191	2002:03
	AR(1)	2.555658	0.651572	1995:01
	All Coefficients	6.487342	0.350796	1997:03
Swim_pool	Constant	6.06993	0.155954	1995:03
	AR(1)	5.40313	0.208233	1995:03
	All Coefficients	7.559435	0.241074	1996:01

Table 4: Structural break test (Continued)

Implicit Prices		Test Statistics	P-Value	Break Date
Hill	Constant	9.573918	**0.032094**	2000:01
	AR(1)	10.42163	**0.021668**	2000:01
	All Coefficients	10.51157	0.077013	1995:04
MTR	Constant	8.926223	**0.043234**	1997:04
	AR(1)	6.325211	0.139432	1997:04
	All Coefficients	9.172767	0.131301	1997:04
KCR_E	Constant	1.259968	0.959856	1996:01
	AR(1)	1.501236	0.907647	2002:03
	All Coefficients	4.691458	0.609408	1995:03
Water	Constant	3.743696	0.415208	1995:01
	AR(1)	3.193229	0.514888	1995:02
	All Coefficients	4.229138	0.68755	1995:02
HK	Constant	5.043263	0.242821	1997:04
	AR(1)	4.722101	0.278058	1998:03
	All Coefficients	5.883314	0.427663	1998:03
KL	Constant	1.960549	0.79552	2002:03
	AR(1)	2.036642	0.776615	2002:03
	All Coefficients	3.535789	0.80512	1994:01
Intercept	Constant	8.096737	0.063119	1997:04
	AR(1)	6.450738	0.131931	1997:04
	All Coefficients	9.499481	0.115518	1997:04

Figure 4: Implicit prices of the "intercept" term



Concluding Remarks

This paper studies the "stability" of the implicit prices of different housing attributes. The notion that the implicit prices of housing attributes are not constant over time can trace back to Edmonds (1985), at least. Since then, much effort has been devoted to modify and improve the traditional hedonic pricing approach. Less effort, however, has been invested to formally study the "stability" of the implicit prices. This demands a large amount of transactions over a relatively long period of time, so that one can estimate hedonic pricing models repeatedly over different sub-periods, and obtain the time series of implicit prices. This paper takes an initial step towards this direction, with about 220,000 transactions between 1992 and 2005 from the residential property market in Hong Kong. During the sample period, a major financial crisis occurred, and the aggregate housing price swung significantly. This research confirms the conventional wisdom that the implicit prices are not constant over time. On the other hand, the implicit prices do display a certain degree of consistency. For instance, the implicit prices of "area" are always positively significant, whereas the implicit prices of "$area^2$" are always negatively significant, indicating that the marginal utility of area is probably positive, yet diminishing. The implicit prices of "lucky" are typically insignificant. Housing units that are close to subway and train stations are also generally valued higher. Perhaps more importantly, except for a few attributes (e.g., "Hill"), no structural break is detected for the implicit price of any housing attribute, even though the aggregate housing price experiences significant fluctuations.

This naturally leads to many questions. Is it possible that the Asian Financial Crisis did not introduce any structural change in the housing market? Do the movements of macroeconomic variables exert no effect on the valuation of housing attributes? Clearly, more efforts need to be devoted to answer these and related questions.

Moreover, future research can be extended in other directions, as well. First, researchers can await longer time series, and then conduct comparable research on how the property markets were severely affected by the financial crisis. Second, researchers may consider using a regime-switching model to study the time-varying implicit prices. Also, assuming the hedonic price equations used here have controlled for the quality difference among houses, researchers can calculate the residual movement of the housing prices. In the microeconomic literature, price dispersion of non-durable goods has long been studied; however, the price dispersion in housing remains largely unexplored.[30] This research can provide a foundation for further investigation along this line.

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[30] See Leung, Leong and Wong (2006), and Leung and Cheung (2006) for some preliminary efforts.

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