Housing Price Dispersion: an empirical investigation♣

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Abstract

The efficiency of a market is challenged when price dispersion occurs. Previous studies focused on non-durable consumption goods. This study extends the analysis to the case of residential property, whose transactions are dominated by a second-hand market with many potential buyers and sellers. We demonstrate that housing price dispersion exists, and the degree of dispersion changes systematically with some macroeconomic factors, though the second and the third moment of the price distribution react differently to the macroeconomic variables. Some directions for future research are suggested.

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1. Introduction

This study examines empirically the extent of price dispersion in a real estate market. Price dispersion, which means that the same product (such as the same newspapers or the same drugs) can be sold at different prices in different, yet "near," locations at the same time, has long been recognized by economists, as demonstrated by (but not restricted to) the empirical works of Adams (1997), Borenstein and Rose (1994), Eden (2001), Garbade and Silber (1976), Goldberg (2001), Kirman and Vriend (2001), and Sorensen (2000). This phenomenon is in sharp contrast to the standard textbook case of an efficient market and hence attracts a lot of academic attention. On the theoretical front, earlier works on price dispersion are typically static in nature, such as those of Axell (1974), Burdett and Judd (1983), Butters (1977), Diamond (1971), Reinganum (1979), Rob (1985), Salop and Stiglitz (1985), and von zur Muehlen, (1980). Later, some dynamic search theoretic models were developed, which endogenized the searching, pricing, and even the entry and exit behavior of firms, such as those of Benabou (1988, 1992a, b, 1993), Diamond (1987, 1993), Fishman and Rob (1995), and Rach (2001). A common feature of most, if not all, of these papers is that they focused on non-durable consumption goods.

This paper, on the other hand, focuses on housing, which is a durable good. It is also easy to see that the *durability of goods can change the market structure fundamentally*. Durable goods, by definition, can be resold. This is particularly true in the housing market, which is usually dominated by a well developed second-hand market. Buyers today are potential sellers tomorrow. It is therefore difficult to "monopolize" the market simply because there are so many "hidden competitors". Thus, the "market power" explanation for the existence of price dispersion frequently encountered in the

Industrial Organization literature (hereafter *IO*) may not apply in the housing market.[1] Similarly, models based on difference in production cost may not apply neither, as the marginal cost of listing an apartment unit is minimal, and in case the sale takes place, the commission rate vary little across household sellers. On the other hand, for most sellers, they only have their own homes to sell, and they typically do not have much experience selling them. Even if they do, since each house is, by definition, unique, as there are no two houses that occupy exactly the same location, their past experience would not always apply to the latest transaction in a straightforward manner. Thus, price dispersion in the residential property market, if any, can be both interesting and challenging phenomenon for theorists.

Therefore, as Lach (2002) argued, it is not easy for consumers to learn which stores consistently offer lower prices.[2] Interestingly, the same is true for buyers. Some buyers are first-timers in the housing market, and many have little experience buying. It should not be surprising that price dispersion can exist in the housing market. Some studies seem to be consistent with this intuition.[3]

On the other hand, this work also contributes to the housing economics literature. It is well known that real estate is the most important durable consumption good, and at the same time, one of the most important items for most household portfolios. For instance, it has been found that fluctuations in the real estate market could have non-trivial implications for the aggregate economy.[4] Therefore, it is indeed important to understand the real estate market, and this paper focuses on the price

[1] In fact, the pricing behavior in a dynamic setting with strategic considerations can vary significantly across theoretical models, and Folk theorem may apply in some cases and hence empirical testing can be very difficult. For a textbook treatment, see Tirole (1988).
[2] Also note that the marginal cost of "production" is zero, and this means that the dynamic IO model, with switching production cost, may not apply to the housing market.
[3] For instance, see Gabriel, Marquez and Wascher (1992), Baharad and Eden (2004), and the theoretical works of Read (1991).
[4] For instance, see Greenwood and Hercowitz (1991), Kiyotaki and Moore (1997), Ortalo-Magne and Rady (1999), and Chen (2001), and Law (2000) for a survey.

dimension of the trading of real estate. In particular, it attempts to address the following questions: (1) does the degree of price dispersion vary over time? (2) If so, are these variations in line with the business cycles? In other words, can these variations be explained by some macroeconomic variables?[5] In light of this, it is crucially important which measures we use for the degree of price dispersion. Notice that the notion of "dispersion" is somehow *vague*, and in the empirical literature, it is typically measured by the standard deviation of the distribution or the coefficient of variation.[6] A higher value of standard deviation means a higher degree of dispersion.

However, the distribution of prices and/or rates of return is typically asymmetric, and the standard deviation may be *insufficient* to capture the "*extent* of the dispersion". In fact, it is now an established result in the finance literature that the distribution of returns is highly skewed, and several theories have been proposed to account for it.[7] Since this study focuses on real estate, which is an important asset, it would employ both the standard deviation and the skewness of the housing price distribution, and study whether there exists some systematic pattern of these measures. The idea is simple. If there are many low-priced real estate units and a few high-priced ones, then the price dispersion among low-priced units would be small, while that between low-priced and high-priced can be captured by a high value of skewness.

As this study extends the analysis to the real estate market, it faces an immediate problem: housing units are not homogeneous. They can differ in terms of attributes

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[5] The literature on the interaction between the housing market and macroeconomy is too large to be surveyed here. See Leung (2004), among others.

[6] For instance, Lach (2002) estimated the log price distribution, and then used different measures, including the coefficient of variation, the ratio of (75% quartile/25% quartile), (95% quantile/5% quartile), (2^{nd} highest/2^{nd} lowest). He showed that the law of one price does not hold. However, he did not use any statistical measure to capture the third moment of the distribution. Also, the asymptotic distributions for measures such as the ratio of (75% quartile/25% quartile) are not clear.

[7] For instance, see Chen, Hong, and Stein (2000) for a discussion of the empirical evidence and Hong and Stein (2002) for a discussion of different theories for the return skewness.

such as age and facilities, but, more fundamentally, location. Therefore, it is very natural to "control" for these differences in the empirical investigation. One of the most widely used strategies is hedonic pricing. Roughly speaking, it decomposes the transaction prices of the same "class" of heterogeneous products into many different parts, according to the "implicit prices" of different attributes, and the residual, which is theoretically the "intrinsic value" of the product is the value of the product after "subtracting" all the observable attributes. To highlight the importance of the heterogeneity of different housing units, this paper will compute and compare price dispersion and price skewness, "controlling" for the difference in attributes (or "qualities").[8]

It is also natural to assume that the degree of price dispersion can change over time, and putting all observations into one regression would inevitably bear the risk of "time aggregation".[9] In fact, Leung, Leong, and Chan (2002) found that the time aggregation problem can be especially serious for the Hong Kong residential market. Therefore, to tackle this potential problem, we split the whole sample into several sub-periods. Then we calculated the (cross-section) price variance and skewness within each period, and traced the evolution of the price dispersion over time.

The evolution of price dispersion and skewness per se should be of independent interest as well. The recent decades have witnessed a blooming of search theoretic models, mainly in labor economics and monetary economics. Apparently, recent development has centered on the modeling of price dispersion, as has been seen in different contexts.[10] However, to the best of our knowledge, there does not exist any

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[8] The current data set does not contain information on the traits of the traders, and does not allow us to identify the change in the bargaining power of traders in different transactions. See the conclusion for more information on this point.

[9] For instance, see Christiano, Eichenbaum, and Marshall (1991), Geltner (1993), for more discussion.

[10] For instance, see Bonmtemps, Robin, and van-den-Berg (2000), Coles (2001), and Rauh (2001), and Pissarides (2000) for a survey.

model that simultaneously endogenizes the price dispersion and the movement of macroeconomic variables. In light of this, this paper attempts to take an initial step in establishing some "stylized facts" between the co-movements of aggregate variables and the price dispersion, which would hopefully inspire future development of the theory.

To compute the price dispersion and skewness of the housing market, it is necessary to choose a "thick" market (i.e., a market with a sufficient amount of trading). This is one of the reasons why the Hong Kong residential housing market during the 1990s was chosen.[11] As shown in Figure 1, while the ratio of the total number of trades relative to the stock is about 5% in the United States, the same ratio was up to 20% in Hong Kong during the 1990s. In addition, there was neither capital control nor a capital gains tax in Hong Kong during that time.[12] An essentially fixed exchange rate was maintained during the sampling period. The education expenditures are equalized across different districts in Hong Kong. In this paper, attention was focused on the "most frequently traded list," and there were 193,121 transactions during the sampling period. In short, it is a choice sample for the research question asked in this paper.

(Figure 1 about here)

It should be noticed that the notion of price dispersion here was adopted from IO literature, and is very different from other notions of price difference in real estate economics literature. For instance, time-on-the-market literature focuses on the relationship between listing price and (actual) trading price, and the listing date and trading date can be very different, while this paper investigates the difference in trading prices of the different housing units for the same period.[13]

The next section provides a more detailed description of the data set. The

[11] Trading information before this period was not accessible to the authors.
[12] Moreover, the individual income tax in Hong Kong is essentially flat.
[13] See Leung, Leong, and Chan (2002) for a study of TOM in Hong Kong.

statistical tools used will be explained, followed by a presentation of the results. The final chapter is the conclusion. All statistical details are provided in the appendices.

2. Hypothesis Testing

One of the objectives of this paper is to test whether the degree of housing price dispersion is related to the macro-economy, broadly defined. Limited by data availability, we selected about ten variables as the macroeconomic indicators in this paper.[14] They reflect different aspects of aggregate economic performance, and could arguably be related to the degree of price dispersion. Since a fully dynamic general equilibrium model that relates the degree of housing market dispersion and aggregate economic conditions has yet to be developed, the following discussion will be less formal than it should be.[15] Nevertheless, it will provide some economic intuition for an empirical analysis to be conducted.

The variables are discussed in order. Real wages can be interpreted as a measure of the opportunity cost of time, and hence substitute for the searching costs. If wages increase, potential buyers would search less intensively. Anticipating that, some house sellers in a decentralized market find it possible to sell their houses at higher prices. Thus, a higher degree of price dispersion will result.

The effect of the real interest rate may be more complicated. A higher interest rate means that the opportunity cost for sellers turning down an existing offer and waiting for a better one increases. In other words, sellers would be more willing to accept offers and tend to increase price dispersion. On the other hand, a higher real interest rate rewards a patient buyer, and thus, buyers are more willing to search more.

[14] Appendix I gives the descriptions of these macroeconomic variables.

[15] Wheaton (1990) is perhaps the first dynamic general equilibrium model with search and housing. He does not explore the issue of price dispersion, however. For partial equilibrium models, for instance, see Yavas (1992). Anglin (1994, 1999) review the literature and their empirical performance.

This would lead to a lower degree of price dispersion.

In a sense, the inflation rate measures the depreciation rate of the purchasing power of money. Thus, a higher inflation rate means that potential buyers have a higher incentive to close deals. In macroeconomic research, it has been confirmed repeatedly that a higher inflation rate is generally associated with a higher degree of price dispersion. The idea can be traced back to Lucas (1972), and was further developed by Benabou (1988, 1992a, b, 1993). In a decentralized market, sellers who need to post the selling prices of their own products are only informed of the "true price" of the market with time lags. With a higher inflation rate, individual sellers will experience larger variations in the true price, and hence, a higher degree of price dispersion.

By the same token, it seems reasonable to conjecture that faster growing real housing prices mean a higher degree of housing price dispersion. Also, as shown by Stein (1995) and Kiyotaki and Moore (1997), a higher housing price also means a higher net worth for leveraged homeowners, which would enable previously constrained buyers to trade up. This means more trades with the same amount of housing stock. It could increase the degree of housing price dispersion.

A higher level of housing loan available in the market may imply more loans for "buyer-searchers," more buyer-searchers participating in the market, or both. In any case, sellers now have a higher chance of selling their houses even if they priced "a little higher". Needless to say, sellers can still find buyer-searchers with the same amount of money as before. As a result, the degree of housing price dispersion could increase.

Similarly, a higher stock market index implies more potential funds available for home purchases, and could lead to a higher degree of housing price dispersion. On the other hand, a higher unemployment rate implies that there will be fewer potential buyers. Other things being equal, this means that the probability of an individual seller being visited by a potential buyer decreases. If a seller posts a high price and the deal is not made, the seller would then need to wait longer for another potential buyer to visit. Sellers then tend to all lower their asking prices. The degree of price dispersion may therefore decrease.

In a sense, the budget ratio intends to be a "forward-looking variable". For instance, if the government realizes a large surplus (relative to the GDP), it may cut taxes (or increase the tax allowance), and this could result in an increase in future income or wealth. This could, in turn, motivate people to seek opportunities to trade up their houses. Since this ratio is publicly observed, it could change the expectations of potential sellers as well, and affect the degree of the equilibrium housing price dispersion.

By the same token, the trade ratio intends to capture (possible) future changes in income. Since Hong Kong is a small, open economy, it is found that an increase in its net exports would usually be followed by an increase in subsequent economic growth rates.[16] Again, an expected increase in economic growth would motivate some sellers to wait longer for higher prices, while some would take advantage of this upward adjustment by keeping the original price and selling their houses quicker. Thus, this may increase the extent of the equilibrium housing price dispersion.

Finally, the real GDP growth rate captures the possible income effect that may affect the search and bargaining process, which would, in turn, affect the degree of the housing price dispersion at equilibrium. Table 1 summarizes our discussion.

(Table 1 about here)

[16] For instance, see Ho and Wong (2003) and the reference therein.

3. Data Description

In this section, we will describe the sources of data that are employed in this study. There are a total of ten different time series of data that are covered: the transaction price dispersion, which will be explained, and the macroeconomic variables. They include the growth rate of housing loans, the inflation rate, the real aggregate housing price index, the real interest rate, the real stock market index, real wages, the unemployment rate, the budget ratio, the trade ratio, and the real GDP growth rate.

In Hong Kong, the Land Registry is the legal authority that keeps records of property transactions. All the transactions of property rights within Hong Kong have to be registered in the department.

Based on the collected information, the Census and Statistics Department of Hong Kong reports various housing-related data on a regular basis, either quarterly or annually. Almost all the data released, such as rental index and housing price index, is highly aggregated. This macro-type data can only serve well in investigations into the relationship between the housing market and the macro-economy situation, yet it is not suitable for our study, owing to the micro-nature of the price dispersion.

Alternatively, we employed another data set provided by a private research center, the Economic Property Research Center (EPRC). A limitation of the data set is that it is incapable of recording all transactions in the market. To deal with the incompleteness of the data, we confined our study to 44 estates listed as the most frequently traded in the EPRC. The merit of the data set is that the micro-aspect of each transaction can be traced. Not only could prices and corresponding gross feet be traced, but address, floor, and so forth could be as well. Therefore, we can construct a price index, a price dispersion indicator, and also analyze the fluctuations of the index with the quality controlled on each transaction.

The sample period starts from the first quarter of 1992 and ends with the fourth quarter of 2001. Forty-four residential estates representing 193,121 transactions, were selected. To avoid double-counting, only residential housing with the official housing sale and purchase agreement was examined in this study. The samples were grouped quarterly, and the corresponding price dispersion indicators were computed. The average number of transactions was more than 5,000 in each quarter. This provides a foundation for reliable inference.

4. Methodology and Some Empirical Results

In this section, the methodology and statistical procedures are explained in order. First, the calculation of "controlled" housing prices is explained. Then, the calculation of the price dispersion and skewness are presented. The OLS model and VAR modes are elaborated in the exploration of the relationship between price dispersion, skewness, and other macro variables.

Our housing data set, which goes from 1st January 1992 to 31st December 2001, is sub-divided into 44 sub-periods on a quarterly basis. The choice of quarterly frequency has clear justifications. To compute a meaningful price dispersion and skewness measure, it is necessary that the number of transactions in each sub-period be "large enough". In addition, the choice of period length should take into account the special feature of housing transaction. Unlike the trading of financial assets, a transaction in residential housing takes time, and that time period typically depends on different institutional constraints. In Hong Kong, a transaction, starting from the signing of the preliminary selling agreement to the signing of the final agreement for sale and purchase, with the down payment deposited to the seller, typically takes not more than two months to complete, and hence grouping the data by quarters is appropriate. This also automatically eliminates monthly fluctuations. Furthermore, in order to investigate the relationships between the macroeconomic variables and price dispersion and skewness, it is appropriate to have the two groups of variables reported in the same frequency. In Hong Kong, the highest frequency of the official macroeconomic data is quarterly. Using lower frequency data is possible, but some information may be lost in the time aggregation, and thus, using quarterly data is the most appropriate.

During the 1990s, it was not uncommon for Hong Kong to experience double-digit annual inflation. Thus, housing prices in this paper were all converted to real prices. It is also more compatible with economic theory, which typically focuses on real prices rather than on nominal prices. Empirically, the real price of each housing unit is defined as:

$$P_{it}^{R} = \frac{P_{it}^{N}}{CPI(A)_t}, \qquad \text{Eqn. (1)}$$

$t = 1, 2, \ldots, 44$, $i = 1, 2, \ldots, n_t$. The real price of the i^{th} housing unit in period t, P_{it}^{R}, is defined as the nominal price of that, P_{it}^{N}, divided by the Consumer Price Index (A) at period t, $CPI(A)_t$. Notice that the total number of housing units being traded in the market in period t, n_t, is not a constant, as transactions are not evenly distributed within the 44 different quarters. However, real transacted prices suffer from the lack of quality control, and hence may essentially “compare apples to oranges.” To correct for this shortcoming, this paper will employ a hedonic pricing regression approach to eliminate the price difference due to differences in observable attributes.

4.1 Hedonic Pricing

The major obstacle to an accurate measurement of the extent of housing price dispersion is the intrinsic heterogeneity of housing units. To control for the heterogeneity, this study adopted a commonly used approach, namely, the hedonic pricing regression. In each period, a cross-sectional hedonic pricing model, which regresses the transaction prices with the corresponding attributes of the transacted housing units, was estimated.[17] The residual from the regression was interpreted as the "quality-controlled" real housing prices, $P_{it}^{R}(C)$, in the following analysis (henceforth, *controlled prices*). The empirical work of Leung, Cheng, and Leong (2002) showed that a simple linear hedonic pricing equation applied to the Hong Kong data can consistently explain about 80% of the cross-house differences in transaction prices. A summary of the results can be found in Appendix II. Notice that the hedonic pricing equation is estimated independently in each quarter so that it is not only controlled for the heterogeneity of the housing units, but also takes into consideration the fluctuations of the "implicit prices" of different housing attributes.[18]

4.2 Measurements

Following the recommendation of Hardy and Bryman (2004), the *degree* of the housing price dispersion in each quarter was captured by two statistical measures,[19] the standard deviation of the prices (SD captures the *second* central moment of the price distribution) and the price skewness (SK captures the *third* central moment of the price distribution) for the quality-controlled prices ("C"):

$$SD_t(C) = \sqrt{\frac{1}{n_t - 1}\sum_{i=1}^{n_t}\left(P_{it}^{R}(C) - P_{t}^{R}(C)\right)^2} \qquad \text{Eqn. 2a}$$

$$SK_t(C) = \frac{n_t}{(n_t - 1)(n_t - 2)}\sum_{i=1}^{n_t}\left(\frac{P_{it}^{R}(C) - P_{t}^{R}(C)}{SD_t(C)}\right)^3 \qquad \text{Eqn. 2b}$$

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[17] See Malpesszi (2002) for a survey and a justification of this formulation.

[18] See Leung, Cheng, and Leong (2002) for more details. A drawback of this approach is that a *heteroskedastic problem* can emerge, and it may lead to bias in the estimation of the standard deviation of the housing prices. In fact, we found some evidence of *heteroskedasticity.* On the other hand, as shown by Greene (2000), we had a large sample, so the bias was small. The detailed derivations are available on request.

[19] For instance, see Hardy and Bryman (2004).

where $P_t^R(C)$ is the average controlled price at time t, which is zero by construction because an intercept has been included in each hedonic equation. As such, these estimators are free from any scale effects.

The resulting $SD_t(C)$ and $SK_t(C)$ are shown in Figure 2 and Figure 3. Notice also that in the asset pricing literature, the risk measures are sometimes measured by SD and SK as well. However, they are typically related to the fluctuations in price *over time*, whereas here the focus is on the *cross-section* variations in price for the "same" asset within the *same period of time*. Interestingly, the time paths of SD and SK are very different, and as it will be clear later, they also respond to macroeconomic variables differently.

(Figure 2 and Figure 3 about here)

4.3 Stationarity

Before any formal testing, it is necessary to verify that the time series being tested is stationary, because a non-stationary series may cause spurious regression. Therefore, only stationary variables are used for statistical analysis.[20] To check for the stationarity of the studied variables, the Augmented Dickey-Fuller Test (ADF) was applied. If the variable is found to be non-stationary, the first-difference of the variable will be used instead.[21] It will be subject to the same stationarity test, and the same procedure will be repeated until a stationary time series is identified. Table 2 and Table 3 provide the stationarity tests results.

[20] A covariance stationary series y_t fulfills three criteria: $E(y_t)=E(y_{t-s})=\mu$, $E\left[(y_t-\mu)^2\right]=E\left[(y_{t-s}-\mu)^2\right]=\sigma_y^2$, $E[(y_t-\mu)(y_{t-s}-\mu)]=E[(y_{t-j}-\mu)(y_{t-j-s}-\mu)]=\gamma_s$, where μ, σ_y^2, and γ_s are constant. A time series that violates any of the above criteria is non-stationary data. A non-stationary series will cause spurious regression, and therefore only stationary variables are used for statistical analysis. See Greene (2000) for more details.

[21] There are two possible ways to interpret this procedure. First, we can interpret that the model explains the *rate of change* of a certain variable, rather than its level, when the variable is found to be *non*-stationary. The alternative interpretation is to view the first-differencing procedure as a filter, removing the "trend" component of the variable, leaving the (stationary) "cyclical" component for the econometric model to explain. See King and Rebelo (1993) and Baxter and King (1999) for more information.

(Table 2 and Table 3 about here)

4.4 Ordinary Least Squares

As an initial step, Ordinary Least Squares (OLS) is applied to explore the relationship between the macroeconomic variables and the housing price dispersion. Formally, the following regression is run for both indicators of "housing price dispersion":

$$\Phi_j = C_j + \phi_{j0} T_j + \sum_{i=1}^{10} \phi_i X_i + \varepsilon_j , \Phi_j \sim \sigma^C , \kappa^C \qquad \text{Eqn. 3}$$

The dependent variables, $\{\Phi_j\}$, in the models are the measures of the extent of housing price dispersions. The independent variables consisted of a constant term, $\{C_j\}$, a linear trend, $\{T_j\}$, and the ten macroeconomic variables, $\{X_i\}$ (the growth rate of housing loans, the inflation rate, the real aggregate housing price index, the real interest rate, the real stock market index, real wages, the unemployment rate, the budget ratio, the trade ratio, and the real GDP growth rate).[22] The results were clearly unsatisfactory. For one thing, the DW statistics in Table 4 show that there may be serial correlations, and thus the OLS estimates are no longer efficient. We then applied a Feasible Generalized Least Squares (FGLS) model to correct for the possibility of serial correlated error. The results are shown in Table 5.[23]

(Table 4 and Table 5 about here)

Clearly, the results did not confirm the conjectures postulated earlier. After controlling for the quality difference, none of the variables was significant. In particular, search theory would suggest that "labor market variables," such as the real wage and the unemployment rate, would matter, but they do not. "Credit market

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[22] The error term, ε_i, is assumed to be normal distribution with zero mean and a constant variance.
[23] From a comparison of the DW statistics in Tables 4 and 5, it is clear that the serial correlation problem was solved by FGLS. For a textbook treatment of the FGLS estimator, see Wooldridge (2002), especially Chapters 7 and 10.

variables" such as the real interest rate, the inflation rate, etc. did not show any significant relationship neither. Leong (2002) found that the adjusted R^2 for quality-uncontrolled housing price standard deviation is about 0.23. Interestingly, after controlling for the quality difference and serial correlation, the adjusted R^2 is, in fact, 0.21 (Table 5), which is close to the case of quality-uncontrolled housing prices.

The case for housing price skewness is marginally better. As Table 5 shows, only the growth rate of housing loans and the unemployment rate are statistically significant (and they produced the predicted sign). Leong (2002) found that the adjusted R^2 for quality-uncontrolled housing price skewness is about 0.21. Here, after controlling for the quality difference, the adjusted R^2 is 0.26. Again, it seems that controlling for quality difference does not alter the overall predictive power of the empirical model.

One possible explanation for the apparent failure is that the macroeconomic variables are highly correlated, and hence, individually, none of them will be statistically significant. A convenient statistical tool for overcoming this kind of difficulty is by using the principal component method.[24] Basically, we will form a hypothetical series, which is a linear combination of the different macroeconomic variables, with weights corresponding to each eigenvector of the correlation matrix.[25] As shown in Table 6, strong correlations exist among macroeconomic variables. For instance, the de-trended real interest rate, the de-trended (aggregate) housing price index, and the de-trended inflation rate are very high (0.8 or above in absolute value). Also, the budget ratio and the real GDP growth rate exhibit very strong negative correlation (-0.79), as a high growth year would mean more revenue and less expenditure on social

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[24] The principal component method has been widely used in economics and other areas. Among others, see Timm (2002) for a textbook treatment. The authors are grateful to Min Hwang, who suggested the principal component method.

[25] One analogy, as suggested by David Geltner, is that the original time series are like different yet correlated assets. And now we form the same number of uncorrelated portfolios by taking long or short positions in different assets. The authors are very grateful to this suggestion.

welfare. On top of that, some correlations seem to be marginally important. For instance, the correlation between the growth rate of housing loans and the unemployment rate is -0.40 (and this explains why only they are statistically significant in the skewness regression reported in Table 5). Put together, the strong correlations seem to justify the use of the principal component method.

Table 7 and Table 8 provide more information about the principal components used. We decided to use only Principal Components (henceforth ***PC***) 1 to 3 and Table 9 and Table 10 report the results.[26] Again, the OLS model (Table 9) is disappointing, and the results with FGLS are better (Table 10), confirming the intuition that important serial correlations exist in the macroeconomic variables. In particular, the standard deviation of housing price was found to be negatively and significantly related to PC3, which is mainly composed of the growth rate of housing loans (negative weight), the stock market index in real terms (negative weight), and the unemployment rate (Table 7). In other words, an increase in the growth rate of housing loans or the stock market index, or a decrease in the unemployment rate will increase the standard deviation of the housing price dispersion, suggesting an important role of the wealth effect and credit market channel and conforming to our predictions. The results from the skewness regression were even more encouraging. PCs 1 to 3 were statistically significant. Combining this information with Table 7, we drew the following conclusion. The skewness of (quality controlled) housing price will increase, other things being equal, when the real interest rate increases, the (aggregate) housing price decreases, the inflation rate decreases, the budget ratio increases, the trade ratio decreases, the economic growth rate decreases, the growth rate of housing loans increases, the (real) stock price increases, and the unemployment rate

[26] The results with all ten principal components were very similar, as by construction, the principal components were orthogonal among themselves. The details are available upon request.

decreases. Notice that in all of these regressions, *the real wage*, which is a proxy of the shadow price of time, *was never significant*. As shown in Table 10b, these findings only partially confirmed the conjectures summarized in Table 1, suggesting that more theoretical works are needed to explain these "stylized facts".

(Table 6 - 11 about here)

On top of these findings on the "contemporary effects," one may still seek to investigate the "dynamic effects". The justification is obvious. In a dynamic world, different variables interact with one another, blurring the distinction between "independent" and "dependent" variables. In addition, the effect need not be immediate. Therefore, the next subsection is devoted to the empirical results drawn from Vector Auto-Regressive models (VAR), which allow for interactions among different variables and lagged impacts.

4.5 The Vector Autoregressive Model and Granger Causality

Here is our plan of investigation. We will run bi-variate VAR for each possible combination between a measure of the degree of housing price dispersion, and a macroeconomic variable. Then we will apply the Granger Causality test to verify if some macroeconomic variable causes (or is caused by) some measure of the degree of housing price dispersion. We used the Schwarz Bayesian Criterion (SBC) to determine the optimal time lag. This allowed us to have different time lags for different bi-variate VAR regressions, and hence eliminate many unnecessary biases. Specifically, the bi-variate VAR are:

$$X_t = C_1 + \phi_1 T + \sum_{j=1}^{p} \beta_j X_{t-j} + \sum_{j=1}^{p} \gamma_j Y_{t-j} + u_{1t} \qquad \text{Eqn. 4a}$$

$$Y_t = C_2 + \phi_2 T + \sum_{j=1}^{p} \theta_j X_{t-j} + \sum_{j=1}^{p} \lambda_j Y_{t-j} + u_{2t} \qquad \text{Eqn. 4b}$$

where *C1, C2* are constant terms, T is the linear time trend, p is the number of lags, and u_{1t}, u_{2t} are the error terms. The housing price dispersion indicators, σ_t^C and κ_t^C, are represented by X_t, and the macro variables represented by Y_t. In each VAR model, the relationship between any two variables was estimated. In each regression, one variable was selected from the housing price dispersion indicators and one from the macro variables. After we put together the different combinations, we had 20 models and 40 equations to be estimated.[27]

VAR is a good tool for studying the dynamic interactions between two variables in the sense that it provides estimates for the impact of each lag of one variable on another one. However, when there are more than one lag, and the signs are not the same, the results from the VAR models are often difficult to interpret. Here, we turn to the Granger Non-Causality (GNC) test, which answers the question of whether the impacts of all lags of one variable, summed up in a certain sense, are significant enough to "cause" another variable. Statistically, this means that it is testing the hypothesis that:

$$H_0^x : \gamma_j = 0 \quad \text{for all j} \qquad \text{Eqn. 5a}$$

$$H_1^x : \gamma_j \neq 0 \qquad \text{Eqn. 5b}$$

$$H_0^y : \theta_j = 0 \quad \text{for all j} \qquad \text{Eqn. 5c}$$

$$H_1^y : \theta_j \neq 0 \qquad \text{Eqn. 5d}$$

In each model, we had two equations and tested two GNC. The null hypothesis is that the selected macro variable does not explain the selected housing price dispersion indicator, and the alternative is that they have a relationship.

(Table 12 about here)

The results in Table 12 are clear. For the standard deviation of housing prices, it only Granger causes the budget ratio and the trade ratio. (Standard deviation is

[27] Leong (2002) also provided results for the multi-variate VAR model. Although the results were qualitatively similar, the degree of freedom and precision dropped significantly when we moved from the bi-variate to the multi-variate VAR.

caused by the two variables, and marginally by the real stock market price.) For the skewness of housing prices, it only causes the trade ratio. For most macroeconomic variables, they are neither caused by nor cause any measure of the housing price dispersion. At least in the bilateral context, the dynamic interactions between the housing price dispersion measures and macroeconomic variables are weak.

Again, one may object that in practice, macroeconomic variables are correlated, as early results have confirmed. Thus, we rephrased our question as: does the macroeconomy factor, *broadly defined*, matter for the housing price dispersion? To answer this, we again utilized the principal component method, and used only PCs 1 to 3, and re-ran 2 bi-variate VAR between the principal component (PC) and the measures of the housing price dispersion. Only PC2, which was mainly driven by the budget ratio and the trade ratio, which are "forward-looking variables" by construction, displayed a causality relationship with the standard deviation of housing prices in both directions. For housing price skewness, no causality relationship was found.

Again, this finding seemed to suggest that there is only limited dynamic interaction between the macroeconomic variables and the housing price measures. Most of the effect from the macroeconomic variables to the housing price dispersion measures was contemporary. It might be that the economic transmission mechanism was very efficient, or simply that the sampling period of the current data set was not long enough. More research is needed.

4.6 Volume[28]

This subsection studies the relationship between trading volume and the degree of price dispersion. In the literature, it is well known that the (mean of) housing price and trading volume are positively correlated.[29] However, it is not clear whether the degree

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[28] The authors want to thank William Wheaton for suggesting this subsection.

[29] The literature is too large to be reviewed here. See Leung, Lau and Leong (2002), Leung and Feng (2005), Yiu, Hui and Wong (2005) and the reference therein.

of housing price dispersion should be positively correlated with the trading volume. If the informational frictions in the housing market is small like equity, then it is natural to expect that as the trading volume increases, the degree of price dispersion should decrease. On the other hand, if the informational friction is large, it seems reasonable to expect that an increase in trading volume means a higher heterogeneity in traders, and probably a higher degree of price dispersion. As shown by figure 1, the trading volume does fluctuate significantly during the sampling period, thus, it seems to be a natural exercise to conduct. In particular, we will investigate whether there is any contemporary or dynamic relationship between the trading volume, and the degree of housing price dispersion (as measured by SD and SK)

The trading volume data comes from the Land Registry, which records all transactions of building units in Hong Kong. It is measured by the number of Sales and Purchase Agreements in each quarter. From 1992 to 2001, trading volume ranged from 18,260 to 62,843 transactions per quarter, with an average of 30,441. This high frequency of transactions reinforces the activeness of the Hong Kong real estate market compared to other countries.

A simple correlation analysis revealed that SD and trading volume[30] are *significantly* positively correlated, with a correlation coefficient (p) of 0.34. However, there is little correlation between SK and trading volume (p=0.06). Granger causality test was then applied to examine if price dispersion and trading volume has any dynamic relationship. No significant result was found, except for the finding that SK Granger causes trading volume at the 10% level.

Table 13: Trading Volume and Price Dispersion

Variable (Y)	Trading Volume	
	F-stat	Prob

[30] The ADF test revealed that the volume series is non-stationary at the level and so first-difference was applied to detrend it.

SD(C) → Y	0.3081	0.5824
Y → SD(C)	0.1927	0.6634
SK(C) → Y	3.0273	0.0907*
Y → SK(C)	0.6933	0.4107

* means at 10% statistical significance

5. Concluding Remarks

The price dispersion phenomenon has been receiving increased attention recently.[31] This paper takes a preliminary step in investigating the price dispersion of a durable consumption goods in the context of the Hong Kong housing market. It seems that even after controlling for the quality difference of the houses being traded over time, the macroeconomy factor, broadly defined, affected the extent of the housing price dispersion (measured by standard deviation or skewness). In terms of contemporaneous relationship, the skewness of the housing price seemed to be much more responsive to the movement of the macroeconomic variables, although the signs of some of the variables were not as expected. On the other hand, dynamic interaction, or the "feedback" effect, was only found in between the standard deviation of the housing prices and a group of highly correlated, and "forward-looking" macroeconomic variables (the budget ratio, the trade ratio and the economic growth rate). The results with the trading volume confirm such impression. While SD is significantly positively related to the trading volume of the market, the SK is not. This may be counter-intuitive because one may expect that as the trading volume increases, the heterogeneity of housing market traders increases and hence SK may be correlated to the trading volume, yet it is not the case. It seems appropriate to conclude that the second moment (SD) and the third moment (SK) of the price distribution capture *very different* aspects of the market. To the best of our knowledge, we are not aware of any

[31] For instance, see Hong, McAfee, and Nayyar (2002), Curtis and Wright (2004), Kamiya and Sato (2004), and the references therein.

theoretical discussion of why aggregate variables would impact the two moments of price distribution so differently. Clearly, while this paper has established these stylized facts, many questions were still left unanswered.

A natural step forward would be to investigate the precise economic mechanism through which the degree of housing price dispersion is affected by the macroeconomic factor, among other factors. This would demand the use of a richer data set. For instance, Yavas, Miceli, and Sirmans (2001) reported that the existence of an intermediary decreases the likelihood of an agreement and increases the time to reach an agreement. Thus, an accurate measure of real estate agency service may bear some implications for the price dispersion. Harding, Rosenthal, and Sirmans (2003) reported that household observable characteristics (such as gender and the number of kids) would influence the bargaining power of buyers and sellers. Thus, variations in the composition of traders over the business cycles may affect the degree of the price dispersion. Merlo and Ortalo-Magne (2004) analyzed a data set with all the listing price changes and offers ever made. They found that listing price reductions were fairly infrequent, but usually large when they happened. This phenomenon seems to be inconsistent with many existing theories. The current data set, however, does not contain any of these information and preclude us from further investigation.[32]

Further research can be extended in several directions. First, future research can extend the investigation with a longer time series or data from different cities. Second, theoretical models can be built to mimic the findings here. In fact, if price dispersion in non-durable goods consumption is a concern for the market efficiency, price dispersion in durable goods could well be a bigger concern, as the "distortion" can have a dynamic

[32] Seslen, Wheaton and Pollakowski (2004) find that both the spatial and the (local) risk factor are important in the pricing of housing in 4 major cities in the U.S.. In the context of Hong Kong, since most buildings we consider have 20 floors or more, and each floor typically contains 6 or more apartment units, the spatial factor may not be as important.

effect. In particular, the price dispersion in the housing market remains largely unexplored. Third, the time-on-the-market (TOM) vary systematically over the economic cycles, and this may affect the pricing behavior,[33] and as a result, how the degree of price dispersion change over time. Future work may consider incorporating these information into the model. This study simply took a preliminary step towards this direction and further investigations should be encouraged..

[33] Among others, see Fisher et. al. (2003) for more discussion on this.

6. Reference

1. Adams, A. F., III. (1997), "Search Costs and Price Dispersion in a Localized, Homogeneous Product Market: Some Empirical Evidence", *Review of Industrial Organization*, 12 (5-6), 801-808.
2. Anglin, P. (1994), "A summary of some data on buying and selling houses," University of Windsor, mimeo.
3. Anglin, P. (1999), "Testing some theories of bargaining," University of Windsor, mimeo.
4. Axell, B. (1974) "Price Dispersion and Information-An Adaptive Sequential Search Model," *Swedish Journal of Economics,* 76(1): 77-98.
5. Baharad, E. and B. Eden (2004), "Price Rigidity and Price Dispersion: Evidence from Micro Data," *Review of Economic Dynamics,* 7(3): 613-41.
6. Baxter, M. and R. King (1999), "Measuring business cycles: approximate band-pass filters for economic time series," *Review of Economics and Statistics*, 81, 585-593.
7. Benabou, R. (1988), "Search, Price Setting and Inflation", *Review of Economic Studies*, 55 (3), 353-376.
8. Benabou, R. (1992a), "Inflation and Markups: Theories and Evidence from the Retail Trade Sector," *European Economic Review*, 36 (2-3), 566-574.
9. Benabou, R. (1992b), "Inflation and Efficiency in Search Markets," *Review of Economic Studies*, 59 (2), 299-329.
10. Benabou, R. (1993), "Search Market Equilibrium, Bilateral Heterogeneity, and Repeat Purchases," *Journal of Economic Theory*, 60 (1), 140-158.
11. Bontemps, C.; J. M. Robin and G. J. Van Den Berg (2000), "Equilibrium Search with Continuous Productivity Dispersion: Theory and Non-parametric Estimation," *International Economic Review*, 41 (2), 305-358.
12. Borenstein, S. and N. L. Rose (1994), "Competition and Price Dispersion in the U.S. Airline Industry," *Journal of Political Economy*, 102 (4), 653-683.
13. Burdett, K. and K. Judd (1983), "Equilibrium Price Dispersion," *Econometrica*, 51 (4), 955-969.
14. Butters, G. (1977), "Equilibrium Distributions of Sales and Advertising Prices," *Review of Economic Studies,* 44(3): 465-91.
15. Cason, T. and D. Friedman (2003), "Buyer search and price dispersion: a laboratory study," *Journal of Economic Theory*, 112, 232-260.
16. Chen, N. K. (2001), "Bank net worth, asset prices and economic activity," *Journal of Monetary Economics*, 48, 415-436.
17. Chen, J.; H. Hong and J. Stein (2000), "Forecasting crashes: trading volume, past returns and conditional skewness in stock prices," *Journal of Financial Economics*, forthcoming.
18. Christiano, L., M. Eichenbaum and D. Marshall (1991), "The permanent income hypothesis revisited," *Econometrica*, 59, 397-424.
19. Coles, M. (2001), "Equilibrium wage dispersion, firm size, and growth," *Review of Economic Dynamics*, 4, 159-87.
20. Curtis, E. and R. Wright (2004), "Price setting, price dispersion, and the value of money: or, the law of two prices," *Journal of Monetary Economics*, 51, 1599-1621.
21. Diamond, P. (1971), "A Model of Price Adjustment," *Journal of Economic Theory*, 3 (2), 156-168.
22. Diamond, P. (1987), "Consumer Differences and Prices in A Search Model," *Quarterly Journal of Economics*, 102 (2), 429-436.
23. Diamond, P. (1993), "Search, Sticky Prices, and Inflation," *Review of Economic Studies*, 60 (1), 53-68.
24. Eden, B. (2001), "Inflation and Price Adjustment: An Analysis of Micro-data," *Review of Economic Dynamics*, 4 (3), 607-636.
25. Fisher, J.; D. Gatzlaff, D. Geltner and D. Haurin (2003), "Controlling for impact of variable liquidity in commercial real estate price indices," *Real Estate Economics*, 31(2), 269-303.
26. Fishman, A. and R. Rob (1995), "The durability of information, market efficiency and the size of firms," *International Economic Review*, 36(1), 19-36.

27. Gabriel, S.; J. S. Marquez and W. L. Wascher (1992), "Regional House Price Dispersion and Interregional Migration," *Journal of Housing Economics*, 2 (3), 235-256.
28. Garbade, K. and W. L. Silber (1976), "Price Dispersion in the Government Securities Market," *Journal of Political Economy*, 84 (4), 721-740.
29. Geltner, D. (1993), "Temporal Aggregation in Real Estate Return Indices," *American Real Estate and Urban Economics Association Journal,* 21(2): 141-66.
30. Goldberg, P. (2001), "The Evolution of Price Dispersion in the European Car Market," *Review of Economic Studies*, 68 (4), 811-848.
31. Greene, W. (2000), *Econometric Analysis*, 4th ed., New Jersey: Prentice Hall.
32. Greenwood, J. and Z. Hercowitz (1991), "The allocation of capital and time over the business cycle," *Journal of Political Economy*, 99, 1188-1214.
33. Harding, J.; S. Rosenthal and C. F. Sirmans (2003), "Estimating bargaining power in the market for existing homes," *Review of Economics and Statistics*, 85(1), 178-188.
34. Hardy, M. and A. Bryman (2004), *Handbook of Data Analysis*, London: Sage Publications.
35. Ho, L. and G. Wong (2003), "The nexus between housing and the macro economy: Hong Kong as a case study," Lingnan University, mimeo.
36. Hong, H. and J. Stein (2002), "Difference of opinion, short-sales constraints and market crashes," *Review of Financial Studies*, forthcoming.
37. Hong, P., P. McAfee, and A. Nayyar (2002), "Equilibrium Price Dispersion with Consumer Inventories," *Journal of Economic Theory,* 105(2): 503-17.
38. Kamiya, K. and T. Sato (2004), "Equilibrium Price Dispersion in a Matching Model with Divisible Money," *International Economic Review,* 45(2): 413-30.
39. King, R. and S. Rebelo (1993), "Low frequency filtering and real business cycles," *Journal of Economic Dynamics and Control,* 17, 207-231.
40. Kirman, A. and N. J. Vriend (2001), "Evolving Market Structure: an ACE Model of Price Dispersion and Loyalty," *Journal of Economic Dynamics and Control*, 25 (3-4), 459-502.
41. Kiyotaki, N. and J. Moore (1997), "Credit cycles," *Journal of Political Economy*, 105, 211-248.
42. Lach, S. (2002), "Existence and persistence of price dispersion: an empirical analysis," *Review of Economics and Statistics,* 84(3): 433-44.
43. Law, W. L. (2000), *Hong Kong Property Market: a comparison between company and individual investors*, unpublished master thesis, Chinese University of Hong Kong.
44. Leong, Y. C. F. (2002), "Housing price dispersion: an empirical investigation," unpublished master thesis, Chinese University of Hong Kong.
45. Leung, C. K. Y. (2004), "Macroeconomics and Housing: a review of the literature," *Journal of Housing Economics,* 13, 249-267.
46. Leung, C. K. Y.; Y. W. Y. Cheng and Y. C. F. Leong (2002), "Does a financial crisis change the demand for housing attributes," Chinese University of Hong Kong, mimeo.
47. Leung, C. K. Y. and D. Feng (2005), "What drives the property price-trading volume correlation? Evidence from a commercial property market," *Journal of Real Estate Finance and Economics*, forthcoming.
48. Leung, C. K. Y.; G. C. K. Lau and Y. C. F. Leong (2002), "Testing alternative theories of the property price-trading volume correlation," *Journal of Real Estate Research*, 23, 253-263.
49. Leung, C. K. Y., Y. C. F. Leong and I. Y. S. Chan (2002) "TOM: why isn't price enough?" *International Real Estate Review*, 5(1), 91-115.
50. Lucas, R. (1972), "Expectations and the neutrality of money," *Journal of Economic Theory*, 4, 103-124.
51. Malpezzi, S. (2002), "Hedonic Pricing models: a selective and applied review," in Housing Economics and Public Policy: Essays in honor of Duncan Maclennan, eds. by T. O'Sullivan, K. Gibb, Oxford: Blackwell; working paper can be downloaded from http://www.bus.wisc.edu/realestate/culer/paper.htm.
52. Merlo, A. and F. Ortalo-Magne (2004), "Bargaining over residential real estate: evidence from England," *Journal of Urban Economics*, 56, 192-216.
53. Mukherjee, C.; H. White and M. Wuyts (1998), *Econometrics and Data Analysis for Developing Countries*, London: Routledge.
54. Ortalo-Magne, F. and S. Rady (1999), "Boom in, bust out: young households and the housing price cycle," *European Economic Review*, 43, 755-766.

55. Pissarides, C. (2000), *Equilibrium Unemployment Theory*, Cambridge: MIT Press.
56. Rauh, M. (2001), "Heterogeneous beliefs, price dispersion, and welfare-improving price controls," *Economic Theory*, 18, 577-603.
57. Read, C. (1991), "A Price Dispersion Equilibrium in a Spatially Differentiated Housing Market with Search Cost," *American Real Estate and Urban Economics Association Journal*, 19 (4), 532-547.
58. Reinganum, J. (1979), "A Simple Model of Equilibrium Price Dispersion," *Journal of Political Economy*, 87 (4), 851-858.
59. Rob, R. (1985), "Equilibrium price distributions," *Review of Economic Studies*, 52(3), 487-504.
60. Salop, S. and J. E. Stiglitz (1985), "Equilibrium Price Dispersion [the Theory of Sales: A Simple Model of Equilibrium Price Dispersion with Identical Agents]," *American Economic Review*, 72 (5), 1191-1194.
61. Seslen, T.; W. Wheaton and H. Pollakowski (2004), "The risk and return to owning housing and "hedonic" spatial equilibrium," MIT, mimeo.
62. Song, F. M. and S. H. Stein (2002), "Vector Autoregression and the dynamic multiplier: a historical review," *Journal of Policy Modeling*, 283-300.
63. Sorensen, A. (2000), "Equilibrium Price Dispersion in Retail Markets for Prescription Drugs," *Journal of Political Economy*, 108 (4), 833-850.
64. Stein, J. (1995), "Prices and trading volume in the housing market: a model with downpayment constraints," *Quarterly Journal of Economics*, 110(2), 379-406.
65. Timm, N. (2002), *Applied Multivariate Analysis*, New York: Springer.
66. Tirole, J. (1988), *The Theory of Industrial Organization*, Cambridge: MIT Press.
67. Von Zur Muehlen, P. (1980), "Monopolistic Competition and Sequential Search," *Journal of Economic Dynamics and Control*, 2 (3), 257-281.
68. Wheaton, W. (1990), "Vacancy, search, and prices in a housing market matching model," *Journal of Political Economy*, 98 (6), 1270-1292.
69. Wooldridge, J. (2002), *Econometric Analysis of Cross Section and Panel Data*, Cambridge: MIT Press.
70. Yavas, A. (1992), "A Simple Search and Bargaining Model of Real Estate Markets," *American Real Estate and Urban Economics Association Journal,* 20(4): 533-48.
71. Yavas, A.; T. Miceli and C. F. Sirmans (2001), "An experimental analysis of the impact of intermediaries on the outcome of bargaining games," *Real Estate Economics*, 29(2), 251-276.
72. Yiu, C. Y.; E. C. M. Hui and S. K. Wong (2005), "Lead-lag relationship between the real estate spot and forward contracts market," *Journal of Real Estate Portfolio Management*, forthcoming.

Figure 1: The Degree of Market Activeness

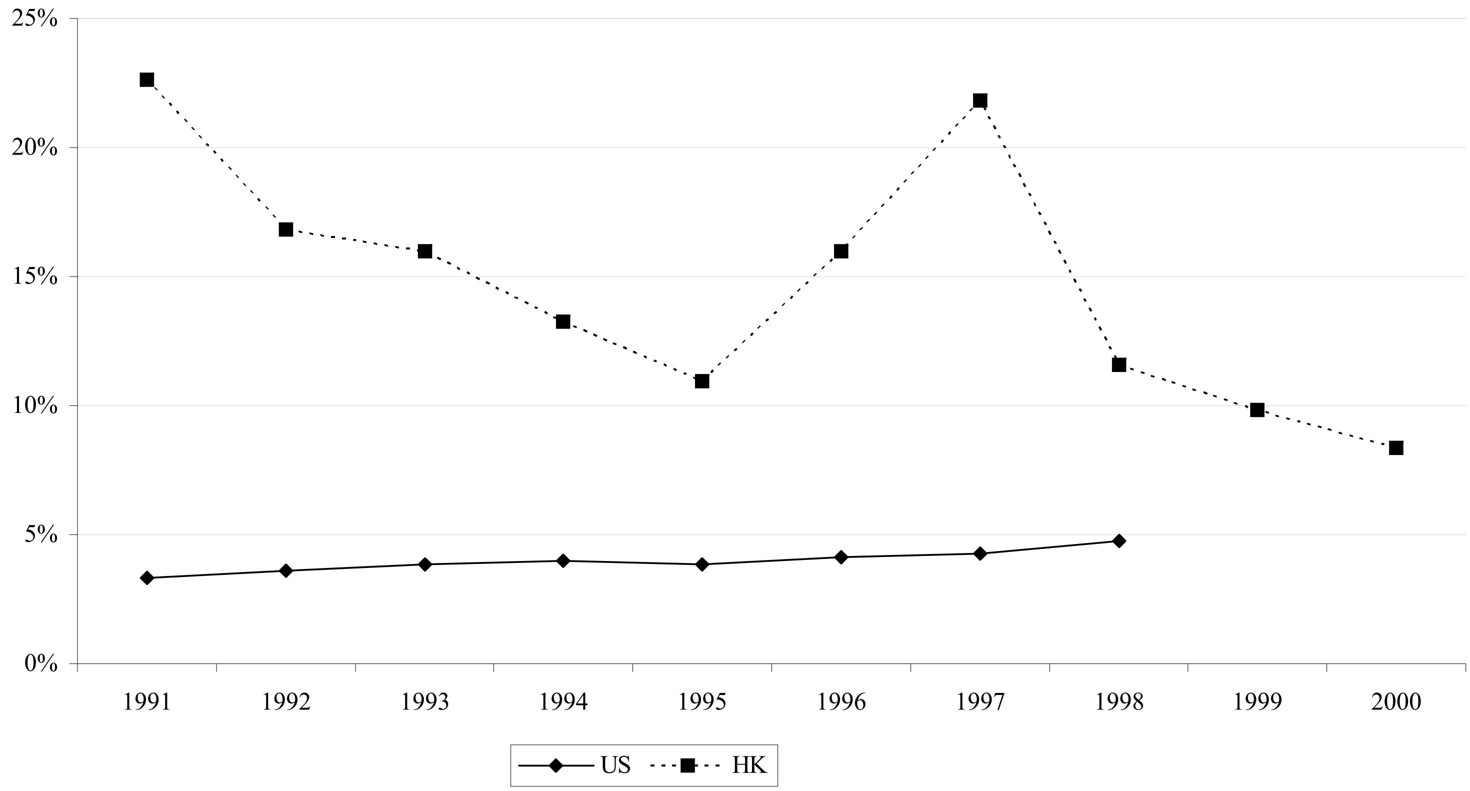

Figure 2: Standard Deviation of the Controlled Prices

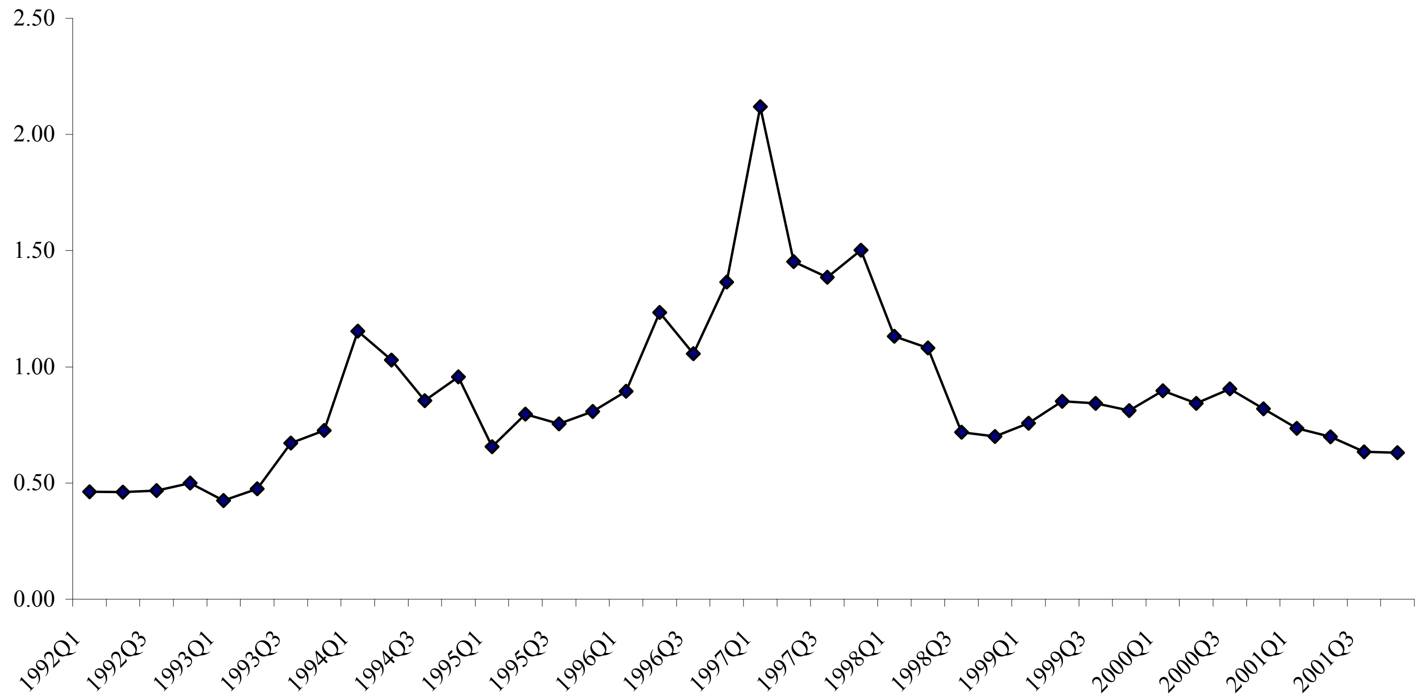

Figure 3: Skewness of the Controlled Prices

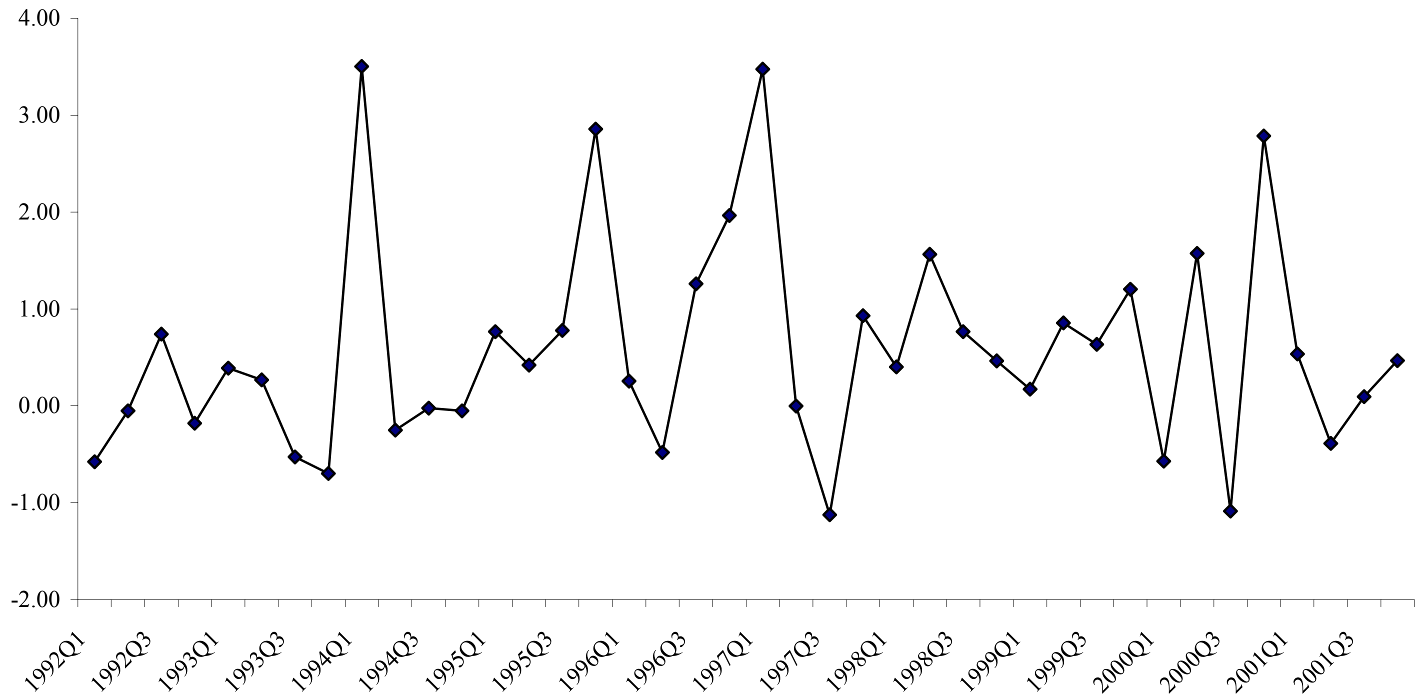

Table 1: Hypotheses

	Standard Deviation	Skewness
Growth rate of Housing Loans	+	+
Inflation Rate	+	+
Real Aggregated Housing Price Index	+	+
Real Interest Rate	+/-	+/-
Real Stock Market Index	+	+
Real Wages	+	+
Unemployment Rate	-	-
Budget Ratio	+	+
Trade Ratio	+	+
Real GDP Growth Rate	+	+

Table 2: Augmented Dickey Fuller Tests

Description	Variable	Stationary
Level:		
Price Dispersion (standard deviation)	SD(C)	No
Price Dispersion (skewness)	SK(C)	Yes
Growth rate of Housing Loans	GL	Yes
Real Aggregated Housing Price Index	HPI	No
Inflation Rate	IR	No
Real Interest Rate	R	No
Real Stock Market Index	SI	No
Unemployment Rate	UR	No
Real Wages	W	No
Budget Ratio	BR	Yes
Trade Ratio	TR	Yes
Real GDP Growth Rate	GR	Yes
First difference:		
Price Dispersion (standard deviation)	d(SD(C))	Yes
Real Aggregated Housing Price Index	d(HPI)	Yes
Inflation Rate	d(IR)	Yes
Real Interest Rate	d(R)	Yes
Real Stock Market Index	d(SI)	Yes
Unemployment Rate	d(UR)	Yes
Real Wages	d(W)	Yes

Table 3: Distribution of de-trended variables

	Variable	Positive	Negative
Price Dispersion (standard deviation)	d(SD(C))	46%	**54%**
Real Aggregated Housing Price Index	d(HPI)	38%	**62%**
Inflation Rate	d(IR)	38%	**62%**
Real Interest Rate	d(R)	**59%**	41%
Real Stock Market Index	d(SI)	**59%**	41%
Unemployment Rate	d(UR)	44%	**56%**
Real Wages	d(W)	**72%**	28%

The details are available upon request.

Table 4: OLS models with different macro indicators

	SD(C)	SK(C)
Constant	-0.0295	0.1666
Linear Time Trend	-0.0005	0.0175
Growth rate of Housing Loans	0.8905	-0.7179
Real Interest Rate	-10.3240	-0.5643
Real Aggregate Housing Price Index	0.1802	-75.6547
Inflation Rate	-9.0434	33.5433
Real Stock Market Index	0.0000	-0.0002
Unemployment Rate	-7.4988	-29.5931
Real Wages	-0.1470	4.3239
Budget Ratio	1.1216	4.7536
Trade Ratio	0.0568	-3.1147
Real GDP Growth Rate	0.3157	0.9680
R^2	0.2566	0.1416
$\overline{R}^2$	-0.0462	-0.2081
DW	2.4641	2.3176

*** means at 1% statistical significance
** means at 5% statistical significance
* means at 10% statistical significance
The details are available upon request.

Table 5: FGLS models with different macro indicators

	SD(C)	SK(C)
Constant	-0.0609	-0.0111
Linear Time Trend	0.0008	0.0215
Growth rate of Housing Loans	0.7620	4.1616 *
Real Interest Rate	-6.7401	-0.7815
Real Aggregate Housing Price Index	-50.9153	-102.0651
Inflation Rate	20.8097	18.6422
Real Stock Market Index	0.0001	-0.0001
Unemployment Rate	-15.2598	-83.0981 **
Real Wages	0.1898	0.2937
Budget Ratio	-0.1265	-1.1255
Trade Ratio	0.0276	-2.5353
Real GDP Growth Rate	-1.0545	-7.4356
R^2	0.4924	0.5878
$\overline{R}^2$	0.2054	0.2624
DW	2.0005	2.1326

*** means at 1% statistical significance
** means at 5% statistical significance
* means at 10% statistical significance
The details are available upon request.

Table 6: Correlation Coefficients of Macro Indicators

	GL	d(R)	d(HPI)	d(IR)	d(SI)	d(UR)	d(W)	BR	TR	GR
GL										
d(R)	0.06									
d(HPI)	0.06	-0.80								
d(IR)	0.11	-0.82	0.99							
d(SI)	0.05	0.07	-0.11	-0.09						
d(UR)	-0.40	0.17	-0.28	-0.32	-0.17					
d(W)	0.12	0.39	-0.34	-0.33	0.19	0.13				
BR	0.29	0.19	-0.08	-0.06	0.01	0.04	0.20			
TR	-0.35	-0.16	-0.02	-0.06	0.13	-0.06	0.19	-0.33		
GR	-0.01	-0.15	0.10	0.11	0.03	-0.31	-0.06	-0.79	0.38	

Table 7: Principal Components of Macro Indicators

Principal Component (PC)	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
GL	-0.02	-0.33	**-0.57**	0.26	-0.23	0.19	-0.60	0.09	-0.19	-0.01
d(R)	**0.49**	0.04	-0.14	0.22	0.02	-0.06	0.33	0.73	-0.19	0.08
d(HPI)	**-0.51**	-0.17	0.05	-0.16	-0.11	0.14	0.19	0.39	-0.13	-0.67
d(IR)	**-0.52**	-0.19	0.01	-0.15	-0.10	0.14	0.16	0.26	-0.03	0.74
d(SI)	0.07	0.09	**-0.40**	-0.51	0.69	0.29	-0.06	0.08	0.02	-0.01
d(UR)	0.23	0.03	**0.59**	-0.11	-0.07	0.57	-0.42	0.25	0.10	0.02
d(W)	0.29	0.06	-0.26	-0.43	-0.60	0.35	0.34	-0.24	-0.04	-0.01
BR	0.19	**-0.56**	-0.02	-0.29	-0.08	-0.33	-0.07	0.17	0.65	-0.04
TR	-0.06	**0.48**	-0.02	-0.45	-0.26	-0.49	-0.41	0.26	-0.16	0.04
GR	-0.21	**0.52**	-0.27	0.29	-0.12	0.20	0.01	0.17	0.67	-0.04

Table 8: Explanatory power of each principal components of Macro Indicators

PC	Percentage explained
1	**31.58%**
2	**21.08%**
3	**15.08%**
4	11.10%
5	8.10%
6	6.13%
7	3.78%
8	1.78%
9	1.28%
10	0.09%

Table 9: OLS models with principal components

	SD(C)	SK(C)
Constant	-0.0011	0.3646
Linear Time Trend	0.0003	0.0121
PC1	-0.0013	0.1180
PC2	-0.0376	-0.1943
PC3	-0.0561 *	-0.0383
R^2	0.1467	0.1011
$\overline{R}^2$	0.0463	-0.0046
DW	2.4518	2.4541

*** means at 1% statistical significance
** means at 5% statistical significance
* means at 10% statistical significance

Table 10: FGLS models with principal components

	SD(C)	SK(C)
Constant	0.0273	0.1827
Linear Time Trend	-0.0011	0.0217 ***
PC1	0.0000	0.1668 ***
PC2	0.0036	-0.2436 ***
PC3	-0.0720 ***	-0.2336 **
R^2	0.2923	0.4704
$\overline{R}^2$	0.1507	0.3074
DW	1.9255	1.9990

*** means at 1% statistical significance
** means at 5% statistical significance
* means at 10% statistical significance

Table 11: Hypotheses and Findings from FGLS

	Hypothesis	SD	SK
Growth rate of Housing Loans	+	+	+
Inflation Rate	+		-
Real Aggregated Housing Price Index	+		-
Real Interest Rate	+/-		+
Real Stock Market Index	+	+	+
Real Wages	+		
Unemployment Rate	-	-	-
Budget Ratio	+		+
Trade Ratio	+		-
Real GDP Growth Rate	+		-

(only 5% significance or below are shown)

Table 12: Granger Causality Test

Variable (Y)	GL		d(R)		d(HPI)		d(IR)		d(SI)	
	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob
SD(C) → Y	0.2119	0.6453	0.1426	0.7057	0.0110	0.9166	0.0067	0.9350	0.0409	0.8398
Y → SD(C)	1.8686	0.1716	0.8011	0.3708	0.1908	0.6623	0.1891	0.6636	3.8288	0.0504*
SK(C) → Y	1.6178	0.2034	0.0105	0.9183	0.0128	0.9100	0.0027	0.9586	2.1228	0.1451
Y → SK(C)	0.0990	0.7531	0.1059	0.7449	0.0268	0.8700	0.0215	0.8834	0.6379	0.4245

Variable (Y)	d(UR)		d(W)		BR		TR		GR	
	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob
SD(C) → Y	0.6138	0.4333	0.0171	0.8960	19.0106	0.0008***	11.4891	0.0216**	6.0114	0.1983
Y → SD(C)	0.8482	0.3571	0.0602	0.8062	9.1348	0.0578*	9.5683	0.0484**	5.5701	0.2336
SK(C) → Y	0.7305	0.3927	0.2505	0.6167	0.1246	0.9396	6.5006	0.0108**	1.2312	0.8729
Y → SK(C)	0.2876	0.5918	0.0027	0.9589	3.9096	0.1416	0.1101	0.7401	3.4634	0.4835

Variable (Y)	PC1		PC2		PC3	
	Chi sq.	Prob	Chi sq.	Prob	Chi sq.	Prob
SD(C) → Y	0.0063	0.9368	27.2666	0.0000***	0.4942	0.4821
Y → SD(C)	0.4831	0.4870	8.4641	0.0760*	0.3363	0.5620
SK(C) → Y	0.0283	0.8664	3.1139	0.3744	1.8814	0.1702
Y → SK(C)	0.0021	0.9637	3.9646	0.2653	0.0004	0.9836

*** means at 1% statistical significance
** means at 5% statistical significance
* means at 10% statistical significance

Appendix I: Description of Macroeconomic Variables

The sources of macroeconomic data are from the Monthly Statistics Bulletin and the Hong Kong Monthly Digest of Statistics published by the Hong Kong Monetary Authority and the Hong Kong Census and Statistics Department, respectively.

7. The growth rate of housing loans (GL)

The rate is equal to the growth rate of the residential mortgage loan. The loans are granted by 33 authorized institutions to professional and private individuals for the purchase of residential properties in Hong Kong, other than flats in the Home Ownership Scheme, the Private Sector Participation Scheme, and Tenants Purchase Scheme, regardless of whether the properties are intended for occupation by the borrowers or for other purposes. The 33 authorized institutions accounted for about 90% of the total loans granted by all authorized institutions as of March 2000.

8. The real interest rate (R)

The real interest rate here is defined as the difference between the nominal interest rate and the inflation rate. The inflation rate has been discussed previously. Our choice of the nominal interest rate is the best lending rate, which reflects the mortgage rate and is the interest rate with the longest time series available.

9. The inflation rate (I.R.)

Based on the information, we adopted the year-on-year rate of change in the Consumer Price Index (CPIA) as an indicator of the inflation rate. The CPIA measures the changes over time in the price level of consumer goods and services generally purchased by households. Based on the household expenditure patterns obtained from the Household Expenditure Survey (HES), the Census and Statistics Department has updated the base period and expenditure weights for compiling the CPIs. In addition to the expenditure weights, a Monthly Retail Price Survey is continuously conducted by the C&SD for the compilation of the CPI.

10. The real stock market index (SI)

The real stock market index is the Hand Seng Index adjusted to the current price level. This index is the key barometer of the Hong Kong stock market and reflects the performance of the market as a whole, since its launched on 24 November 1969.

The constituent stocks of this index are 33 stocks representative of the market. The aggregate market value of these stocks accounts for about 70% of the total market capitalization on the Stock Exchange of Hong Kong Limited. To better reflect the price movements of the major sectors of the market, the 33 constituent stocks are grouped under four sub-indices: Commerce and Industry, Finance, Properties, and Utilities.

11. The real aggregated housing price index (HPI)

The real aggregated housing price index is the property price index adjusted by the general price level. The property price index is based on an analysis of transactions scrutinized by the Rating and

Valuation Department for stamp duty purposes. Transactions that were considered acceptable were included in the analysis. However, those transactions whose dates of sale are more than 12 months prior to the date of scrutiny, were excluded. Also excluded from the analysis were those transactions involving a mix of property classes, premises which had not yet been assessed rates, and domestic premises sold subject to existing tenancies. The date of sale is the date in which an Agreement for Sale and Purchase is signed. It should be borne in mind that a provisional agreement is generally reached 2-3 weeks earlier.

12. The unemployment rate (U.R.)

The unemployment rate refers to the portion of unemployed people in the labor force. The labor force refers to the land-based, non-institutional population aged 15 and over who satisfies the criteria for inclusion in the employed or unemployed population.

The unemployed population comprises all those persons aged 15 and over who fulfill the following conditions: a) have not had a job and have not performed any work for pay or profit during the seven days before enumeration; and b) have been available for work during the seven days before enumeration; and c) have sought work during the 30 days before enumeration.

13. Real wages (W)

The wage rate is basically the price for labor services, and refers to the amount of money paid for normal time of work. It includes, apart from basic wages and salaries, cost of living allowances, meal benefits, commissions and tips, good attendance bonuses, shift allowances, guaranteed year-end bonuses, and allowances. The nominal wage index measures the pure changes in wage rates between two successive reference months. The real wage, obtained by deflating the nominal wage index by the Consumer Price Index (A), indicates changes in the purchasing power of the wages earned.

The budget ratio

It is defined as the government budget surplus/deficit normalized by the GDP, and it has changed significantly over time.

The trade ratio

It is defined as the value of the net export, normalized by the GDP. Notice that throughout the sampling period, Hong Kong has maintained a fixed exchanged rate with the U.S. Dollar and a relative stable exchange rate with the Chinese Renminbi. Since the U.S. and China are Hong Kong's major trade partners, these figures quite accurately reflect the changes in trading activities in real terms, and are relatively less affected by exchange rate fluctuations.

The real GDP Growth rate

It is simply the growth rate of real GDP.

Appendix II: A summary of Hedonic Pricing Equation Results

In our hedonic pricing models, a number of variables were used to capture the structural, neighborhood, locational, and cultural attributes of transacted properties. All properties are selected from big housing estates typically consisting of high-rise residential blocks with 6-8 apartment units on each floor. The high homogeneity of the physical characteristics of our sample allows us to include only a few major structural attributes such as floor levels, flat sizes, and building age. Moreover, as the properties in our sample are estate-type housing units, they normally share a common set of facilities and amenities (e.g. schools and shops) within the same locality. As a result, we only included significant neighborhood attributes that may not be available in every estate such as swimming pools and waters. The locational attributes that we used include proximity to local transportation (i.e. subway or train stations) and district-level measures (i.e. Hong Kong Island, Kowloon, or New Territories). A finer measure of "distance" (e.g. to workplace) was not used because Hong Kong is a very small city and residents in our sample can typically go to the Central Business District in 45 minutes, if not shorter. Finally, we also include a cultural factor to indicate whether or not a flat is located on a floor with lucky numbers. This is a concern (in terms of "feng shui") that may be of particular importance in the Chinese context.

Distribution of Coefficients of the Hedonic Pricing Models

	Positive Significance at 5%	Negative Significance at 5%	Insignificant
Constant	**73%**	20%	8%
Floor level	45%	0%	**55%**
Gross area	**95%**	0%	5%
Lucky floor number	8%	0%	**93%**
Swimming pool	**73%**	13%	15%
Building age	0%	**100%**	0%
Gross area^2	8%	**88%**	5%
Hong Kong Island	**65%**	8%	28%
Kowloon	**90%**	8%	3%
Access to MTR (subway)	**95%**	0%	5%
Access to KCR (railway)	**65%**	3%	33%
Proximity to water	0%	**100%**	0%

(Note: Due to the rounding up error, the numbers of different columns in each row do not always add up to 100%.)

Fitness of the Hedonic Pricing Models

Period	R Square	R Bar Square	Period	R Square	R Bar Square
1992Q1	0.8397	0.8394	1997Q1	0.7176	0.7173
1992Q2	0.8918	0.8916	1997Q2	0.8509	0.8508
1992Q3	0.8377	0.8374	1997Q3	0.8620	0.8617
1992Q4	0.8500	0.8494	1997Q4	0.8077	0.8071
1993Q1	0.8564	0.8561	1998Q1	0.8110	0.8104
1993Q2	0.8684	0.8683	1998Q2	0.7664	0.7655
1993Q3	0.8015	0.8011	1998Q3	0.8141	0.8134
1993Q4	0.8785	0.8782	1998Q4	0.7821	0.7815
1994Q1	0.6928	0.6924	1999Q1	0.8228	0.8221

1994Q2	0.7873	0.7867	1999Q2	0.8397	0.8391
1994Q3	0.8071	0.8065	1999Q3	0.7940	0.7930
1994Q4	0.7981	0.7975	1999Q4	0.8441	0.8434
1995Q1	0.8012	0.8007	2000Q1	0.7859	0.7849
1995Q2	0.7838	0.7834	2000Q2	0.7453	0.7435
1995Q3	0.7501	0.7495	2000Q3	0.7682	0.7667
1995Q4	0.7762	0.7758	2000Q4	0.7025	0.7009
1996Q1	0.7782	0.7779	2001Q1	0.7769	0.7757
1996Q2	0.8065	0.8062	2001Q2	0.7907	0.7896
1996Q3	0.8237	0.8234	2001Q3	0.8120	0.8110
1996Q4	0.8275	0.8274	2001Q4	0.8010	0.7997

Appendix II-b: On Heterogeneity and the Estimation of Price Dispersion

The heteroskedasticity arises in our paper and this appendix we try to offer some formal discussion. To organize that in a more systematic manner, we break it into two parts.

Question 1: is s^2 a biased estimator of σ^2 in the presence of heteroscedasticity?

True model: $y = \mathbf{X}\beta + \varepsilon$ (1a)

Estimated model: $y = \mathbf{X}b + e$ (1b)

Based on the least squares criterion and the full rank assumption, we can derive the expressions for b and e algebraically:

$$b = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'y \tag{2a}$$

$$\begin{aligned} e &= y - \mathbf{X}b \\ &= y - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'y \\ &= \left[\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\right]y \\ &= \left[\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\right](\mathbf{X}\beta + \varepsilon) \\ &= \left[\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\right]\varepsilon \end{aligned} \tag{2b}$$

Since the square bracket term is symmetric and idempotent, we have

$$e'e = \varepsilon'\left[\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\right]\varepsilon \tag{3}$$

A usual estimator of the variance of the disturbance σ^2 is:

$$\begin{aligned} s^2 &= \frac{e'e}{n-K} \\ &= \frac{\varepsilon'\left[\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\right]\varepsilon}{n-K} \\ &= \frac{\varepsilon'\varepsilon}{n-K} - \frac{\varepsilon'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\varepsilon}{n-K} \end{aligned} \tag{4}$$

Now, we assume the disturbance takes the following form (heteroscedastic if $\mathbf{\Omega} \neq \mathbf{I}$):

$E(\varepsilon'\varepsilon) = \sigma^2\mathbf{\Omega}$ where $tr(\mathbf{\Omega}) = n$ for normalization

To check whether s^2 is an unbiased estimator given $\mathbf{X}$,

$$
\begin{aligned}
E(s^2 \mid \mathbf{X}) &= \frac{E(\varepsilon'\varepsilon)}{n-K} - \frac{E\left[\varepsilon'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\varepsilon\right]}{n-K} \\
&= \frac{trE(\varepsilon'\varepsilon)}{n-K} - \frac{trE\left[\varepsilon'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\varepsilon\right]}{n-K} \quad \because \text{the matrix is 1x1 \& equal to its trace} \\
&= \frac{tr(\sigma^2\Omega)}{n-K} - \frac{trE\left[(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\varepsilon\varepsilon'\mathbf{X}\right]}{n-K} \quad \because \text{trace allows cyclic permutations} \\
&= \frac{n\sigma^2}{n-K} - \frac{\sigma^2 tr\left[(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{\Omega}\mathbf{X}\right]}{n-K}
\end{aligned} \qquad (5)
$$

If $\mathbf{\Omega}=\mathbf{I}$ (i.e. homoscedasticity), then $E(s^2|\mathbf{X}) = \sigma^2$ so that s^2 is unbiased. However, **in the presence of heteroscedasticity, s^2 is likely to be a biased estimator of σ^2** and the degree of bias depends on (1) how much the trace of the last term deviates from K and (2) the sample size n.

Question 2: would the above conclusion change if the sample size is large?

In fact, as shown by Greene (2000, p.503-505), the bias becomes negligible as the sample size becomes very large. This requires the assumptions that:

$\lim_{n\to\infty}\frac{X'X}{n}$ and $\lim_{n\to\infty}\frac{X'\Omega X}{n}$ are both positive definite.

$$
\begin{aligned}
\lim_{n\to\infty} E(s^2 \mid X) &= \lim_{n\to\infty}\frac{n\sigma^2}{n-K} - \lim_{n\to\infty}\frac{\sigma^2}{n-K} tr\left[\left(\frac{X'X}{n}\right)^{-1}\left(\frac{X'\Omega X}{n}\right)\right] \\
&= \sigma^2 - 0 \\
&= \sigma^2
\end{aligned} \qquad (6)
$$

The above assumptions are in fact the condition for the consistency of b. Therefore, it suffices to conclude that **asymptotically, s^2 is an unbiased estimator of σ^2 even in the presence of heteroscedasticity**.

Moreover, Greene also shows that if the fourth moment of each disturbance is finite, the variance of s^2 will converge to zero as $n \to \infty$. This implies that plim $s^2 = \sigma^2$ and therefore **s^2 is a consistent estimator of σ^2 even with heteroscedasticity**.

Conclusion

Our sample size is large, with nearly 200,000 data. This means that we can borrow the above asymptotic results to justify that even though heteroskedasticity exists in the hedonic equation, it would only have negligible effect on our use of standard deviation of residuals as an unbiased estimator of price dispersion.

Reference:

Greene, William (2000), *Econometric Analysis*, N. J.: Prentice Hall.

Appendix III: Distribution of Hedonic Characteristics

Mean

	Transacted Price (HK$m)	Floor level	Gross area (sq. ft.)	Lucky floor number	Swimming pool	Building age (year)	HK Island	Kowloon	MTR (subway)	KCR (railway)	Proximity to water
1992	2.3796	15.2186	731.9293	0.0909	0.0141	12.9555	0.2865	0.3027	0.3024	0.0925	0.5855
1993	2.6309	14.9758	730.0551	0.0952	0.0334	12.3427	0.2667	0.2539	0.2974	0.0798	0.6119
1994	3.3930	15.3622	718.4213	0.0943	0.0015	12.5468	0.2355	0.2909	0.2827	0.0550	0.6435
1995	2.8758	15.6959	718.8720	0.0968	0.0030	11.4792	0.3130	0.2788	0.2628	0.0885	0.6620
1996	3.4625	14.9980	744.9639	0.0899	0.0035	12.5237	0.3121	0.3022	0.3176	0.0639	0.6103
1997	4.7336	15.0716	724.5139	0.0931	0.2191	12.1765	0.3072	0.2884	0.2934	0.0729	0.6149
1998	3.1263	15.5149	731.6330	0.0934	0.8196	12.2547	0.3241	0.2944	0.3220	0.0674	0.5934
1999	2.8774	15.0912	738.8292	0.1025	0.7920	13.2203	0.2774	0.3203	0.3528	0.0673	0.5519
2000	2.4648	15.4117	727.2270	0.0979	0.7728	13.2335	0.2807	0.3090	0.3467	0.0708	0.5641
2001	2.1343	15.1142	724.4841	0.0937	0.7805	13.2607	0.2746	0.3220	0.3579	0.0649	0.5543

<u>Standard deviation</u>

	Transacted Price (HK$m)	Floor level	Gross area (sq. ft.)	Lucky floor number	Swimming pool	Building age (year)	HK Island	Kowloon	MTR (subway)	KCR (railway)	Proximity to water
1992	1.2479	9.4338	266.9670	0.2875	0.1177	5.7044	0.4521	0.4594	0.4593	0.2897	0.4926
1993	1.5079	9.2545	251.8380	0.2935	0.1796	5.8140	0.4423	0.4353	0.4571	0.2709	0.4873
1994	2.1029	9.2491	254.1623	0.2922	0.0391	6.0041	0.4243	0.4542	0.4503	0.2279	0.4790
1995	1.6279	9.3600	236.5160	0.2957	0.0545	6.0199	0.4637	0.4484	0.4402	0.2840	0.4730
1996	2.7764	9.5706	290.6684	0.2860	0.0591	6.2353	0.4634	0.4592	0.4655	0.2445	0.4877
1997	3.8007	9.3602	277.1118	0.2906	0.4136	6.1406	0.4613	0.4530	0.4553	0.2600	0.4866
1998	2.1292	9.3505	251.2525	0.2910	0.3845	6.2682	0.4680	0.4558	0.4673	0.2507	0.4912
1999	1.9762	9.1824	271.1652	0.3033	0.4059	6.2336	0.4477	0.4666	0.4779	0.2505	0.4973
2000	1.7750	9.3653	258.2542	0.2972	0.4190	6.4414	0.4494	0.4621	0.4760	0.2565	0.4959
2001	1.4972	9.0939	255.4301	0.2914	0.4139	6.2102	0.4463	0.4673	0.4794	0.2464	0.4971