Financial Crisis and the Comovements of Housing Sub-markets: Do relationships change after a crisis?

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June 2011

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This version: June, 2011

Abstract

This study of the co-movements of the transaction prices and trading volumes reveal that the mean correlation of prices, and trading volumes alike, among different housing sub-markets increases during the market boom. After a financial crisis, the correlations drop dramatically and stay low. The distribution of the correlations changes from skewed to symmetric. All these coincide with the increase in the total variance of prices, as well as the share of the idiosyncratic component in the total variance after the crisis. These findings are consistent to a family of theories which emphasize on "regime switch" in expectation.

JEL Classification Number: E50, G10, G12, R20, R30

Keywords: financial crisis, hedonic pricing, structural break, evolution of valuation, rolling regression

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[♦] *Acknowledgement*: The authors are very grateful to (alphabetical order) Nan-Kuang Chen, Eric Hanushek, Yiting Li, John Quigley, Timothy Riddiough, Jacob Sagi, Ko Wang, anonymous referees, seminar participants of AREUEA meeting, American Real Estate Society meeting, Asian Real Estate Society Meeting, Chinese University of Hong Kong, City University of Hong Kong, Hong Kong Economics Association Meeting, International Conference on Real Estates and the Macroeconomy, National Taiwan University, National University of Singapore, for conversations and comments; City University of Hong Kong for financial support. The work described in this paper was partially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China [Project No. CityU 146407]. The usual disclaimer applies.

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… In the ruin of all collapsed booms is to be found the work of men who bought property at prices they knew perfectly well were fictitious, but who were willing to pay such prices simply because they knew that some still greater fool could be depended on to take the property off their hands and leave them with profit.

From One Hundred Years of Land Values in Chicago, by Homer Hoyt

… Usually the process starts with a trend that is not yet recognized… The trend becomes increasingly dependent on the bias and the bias becomes increasingly exaggerated. During this period, both the bias and the trend may be repeatedly tested by external shocks. If they survive the tests, they emerge strengthened until they become seemingly unshakable…. A point comes when the divergence between belief and reality becomes so great that the participants' bias comes to be recognized…. Eventually, the loss of belief is bound to cause a reversal in the trend…; this trend reversal is the crossover point.... When the process is complete, neither the trend nor the bias remains the same. The process does not repeat itself. There is a regime change....

From Soros on Soros: Staying Ahead of the Curve, by George Soros

1. Introduction

Financial crises, and the possible negative consequences to the general economy, have always been a concern for academic researchers and policy makers alike. The cause of a financial crisis, on the other hand, remains controversial. Clearly, governmental misconduct and credit market "over-expansion" may constitute a significant part of it. Yet the continuous participation of a significant share of the population remains a mystery to be resolved. As the quotations from Homer Hoyt and George Soros suggest, people may indeed be aware of the apparently "irrational component" of the asset pricing during the "boom", yet participate anyway. After a "crash" or a "crisis" in the asset market, however, the people may "change their expectations" and hence a "structural change" could occur. Studying the possible structural change in the asset market, nonetheless, is not straightforward. Corporations may change their management, the focus of their business, the composition of assets they hold, or even merge with other firms after a financial crisis, or even *during* the crisis. It makes the comparison across time periods non-trivial.

This paper suggests that the housing market may provide us some extra information on the issue. Notice that housing units are typically indivisible, and display relatively less variations over time and hence the comparison before and after a crisis may be more manageable. Thus, while the previous efforts typically focus whether the real estate market causes a financial crisis, or the impact on the real estate market of a financial crisis to the real estate market, this paper rather focuses on whether (and how) the co-movements, or more specifically, the price and trading volume correlations among different submarkets *within the same city* change after a financial crisis.[1]

Clearly, the change in the co-movements among different estates after a financial crisis is relevant to several strands of the literature. First, it is related to the pricing of real estate.[2] It is long recognized that factors such as the reputation of the real estate developer and the specific location characteristics tend to change relatively slow. It is especially true for residential housing as the school districts and other "local public

[1] Clearly, it is beyond the scope of this paper to review this literature. See Quigley (1999, 2001), Leung (2004) and the reference therein.
[2] For more details, see Malpezzi (2002), among others.

goods" are proved to be an important empirical determinant for housing prices.[3] The previous literature seems to focus on real estate market in more advanced countries where severe economy-wide crises are relatively rare. In contrast, this paper studies a real estate market which experienced a dramatic crisis and the co-movements among different submarkets potentially change. Since these factors do not change proportionally in the crisis, any changes we can measure can be attributed to the other factors, such as the wealth effect on housing demand, or some expectation factors.

This project may also shed light on the discussion on the correlation between house price and trading volume. Existing dynamic general equilibrium models of housing prices, such as Kan et al (2004), Ortalo-Magne and Rady (2006), Leung et al (2007), among others, has shown that the co-movements among the property price and trading volume at the national or city level are related to the movement of economic fundamentals (such as GDP), the collateral constraints, among other factors. However, the study on the correlations among house prices of different sub-markets, or the correlations among the trading volumes of different sub-markets, are under-explored. In particular, if the price correlations and trading volume correlations at the sub-market level (i.e. within a city) are merely driven by the aggregate shock or financial constraints, we would expect that those correlations among sub-markets would be roughly constant over time. If those sub-market co-movements are driven by search frictions, as in Leung and Zhang (2011), the change of co-movements would likely to be slow, exactly due to the time-consuming process of search and bargaining in the decentralized housing market. And even if the situation is complicated by the fact the banks may have loan preference on some sub-markets over the others, we would still expect those correlations among different real estate developments to change slowly over time, as the search-and-matching process takes time, and the application-and-approval of loans takes time as well. Thus, by simply inspecting the time-pattern of the price and volume correlations among estates would shed light on that literature.

(Table 1 about here)

There is an emerging literature on the "bounded rationality" nature of investors which may shed light on our analysis. For instance, Hong, Kubik and Stein (2004) find that the investors are influenced by the people around them. Hong, Stein and Yu

[3] Again, it is beyond the scope of this paper to review the vast literature. See Weimer and Wolkoff (2001), Hanushek and Welch (2006) and the reference therein.

(2007) propose a model in which agents use over-simplifying models for forecasting. Over time, the discrepancy between the model prediction and the reality reaches a certain threshold and the investors would switch to another forecasting model, resulting in a "paradigm shift" in investment behavior. While these works focus on the stock market, the same logic could also apply to the housing market. In particular, if agents switch their housing price forecasting models, it may lead to a change in the correlations among housing prices, as in Wang et al (2000). Our empirical studies can examine this possibility formally.

This paper is also related to the "financial contagion" literature. Strictly speaking, since this paper studies the interactions among different estates (or, different submarkets) within the same city, it is not a situation of "financial contagion," which tends to focus on the situation where one asset (or market) receives an unfavorable shock and how other assets (or markets) are affected. The ideas, however, are similar and a quick review of that literature may be instructive. Contagion can be defined in many ways and the methodology of the empirical analysis is often chosen accordingly (Pericoli and Sbracia, 2003; Rigobon, 2003). Accordingly to Forbes and Rigobon (2002), contagion is 'a significant increase in cross-market linkages after a shock to one country (or group of countries)'. Thus, many empirical works on contagion focus on the change in the correlation in returns after a shock.

In the context of Hong Kong, it is instructive to consider a real estate development (or simply *estate)* as a submarket.[4] The merits of this approach are clear. Cities and nations may differ in many different aspects which can account for their housing markets to react differently after a crisis. On the contrary, different submarkets within a city share many common "background variables" (including the geography, the labor market condition, and the public finance, even the political and social structure). In this paper, each submarket (or estate) is essentially a collection of high-rise apartment buildings sharing many common features. The nature of high-rise apartment building also makes it very difficult to "extend" or to "alter" the physical

[4] An "estate" in Hong Kong is similar to a "housing development" in the United States. In Hong Kong, an estate is usually constituted by several high-rise buildings built by the same developers on a particular location, with similar if not identical designs and materials, and managed by the same company. This naturally produces a high degree of homogeneity among units which facilitates scientific studies. Size of some of the estates can make them form a distinct community.

structure, which facilitates the comparison across different time periods.[5] In addition, since the boundary of an estate is clearly defined legally and geographically, it does not require further econometric techniques to identify the different submarkets within the city, and allow us to focus on the *change of co-movements* before and after the financial crisis.

It is instructive to start with the general picture of the Hong Kong housing market. Figure 1a displays the *official* housing price indices of Hong Kong, corrected for inflation. The indices are constructed according to the *size* of the housing units, and not necessarily taking the difference in attributes into considerations.[6] Dramatic movements in the nominal housing prices are observed in this period. The indices begin with values slightly under *20* in 1979 and reach their peaks (about *180*) in the 1997 Q4. They then drop to *100* in 1999 Q1, and reach the bottom (about *60*) during 2003, and then increase again.

Interestingly, the indices move very closely together (with correlations higher than 0.9) before the 1997 Asian Financial Crisis. The gaps among the indices, however, seem to widen after the 2003 rebound. Later in this paper we will examine whether the correlations among different estates, after carefully controlling for differences in attributes, also change during the sampling period.

(Figure 1a about here)

Following their insights, this paper also compares the correlations of de-trended housing prices (or, *returns*), as well as the correlations of trading volume among different estates. This approach has several merits. It is "model-free" and non-parametric, and preserves the features of the original time series. It also provides a visualization of the fluctuations of correlation coefficient over time, and the ability to apply the time-series econometric techniques in investigating how the sample correlations change over time. Specifically, we follow the "rolling regression approach" and estimate correlation coefficients among different estates within each

[5] In contrast, some detached houses in the United States would allow for significant extension, including adding a basement, or building a small house on the backyard, etc., which makes the comparison of value across time periods a non-trivial task.

[6] The government officials claim that they do, yet they never fully reveal the details of how those price indices are constructed, and whether those methods have changed over time.

"moving window."[7] This enables us to detect changes in the correlation estimates which are affected by abnormal events, or the "financial crisis shocks" we attempt to identify, given the limiting sample size. It also differentiates our paper from some earlier efforts which adopt the "sampling splitting approach", which rely on the researchers to divide the full sample into "crisis" and "non-crisis" sub-samples, and then compare the estimated correlation coefficient for each sub-sample.[8]

Clearly, there are potentially alternative approaches for this problem. A popular candidate for this class of problem is to use the Dynamic Conditional Correlation (DCC) model, presented by Engle (2002). However, unlike some applications of DCC model in finance or international finance, where there are only a few exchange rates with long time series, we have a much larger number of time series (both prices and trading volumes from 36 estates) but the relatively short time series (14 years of monthly data). In this case, the DCC approach will demand the estimation of several hundred parameters, which is almost infeasible, and definitely not desirable for a dataset with only 168 periods.

On the other hand, this dataset is especially suitable to address our research questions. All the transaction data considered in this paper come from 36 major estates in Hong Kong, which is a balance panel dataset.[9] Our *full sample* contains more than 222,000 transactions in 14 years (1992 to 2005), or on average more than 3,000 transactions in each month. This gives some credibility for the monthly cross-sectional hedonic pricing regression. The choice of data frequency is important to our research question. To search for the timing of sudden change of correlation structure, a higher frequency dataset is desirable, or some information may be lost in the time aggregation process. In practice, however, housing transactions take time and thus

[7] "Rolling regression" has long been used extensively in the economics literature. Among others, see Thoma (1994), Foster and Nelson (1996) and the reference therein.

[8] Some authors have reservations on this approach. Dungey and Zhumabekova (2001) have already demonstrated the problem of choosing a short crisis period as there will be severe power problems for the correlation tests. This also explains why the two standard tests of inter-temporal stability, the Jennrich (1970) and Box (1949) statistics, are un-suitable in the contagion literature as crisis period usually only involves a few observations. See also Dungey et al (2005), Forbes and Rigobon (2002), Solnik, Bourcrelle and Le Fur (1996), among others.

[9] Needless to say, there are new developments in Hong Kong during the sampling period. However, they are relatively few in numbers. The supply of new private housing actually decreases over the sampling period, especially after the Asian Financial Crisis. Among others, see Leung and Tang (2011) for more details. From a theoretical point of view, Leung et al. (2007) show that the class of hedonic equation applied to a balance panel can be justified by a dynamic general equilibrium model. Introducing the new developments into the sample will create an un-balance panel and that is left for future research.

daily or weekly frequency may not be wise choices.[10] In light of these considerations, monthly frequency may be an appropriate compromise. Our balanced panel of estate-level data also helps us to avoid cross-sectional aggregation bias, as unobserved heterogeneity can be better controlled. We also analyze a restricted sample with all the estates with primary market sales removed. We find that the results are in fact similar. To conserve space, those results are not reported here.[11]

Obviously, the desirable features of our dis-aggregate approach come with a price. As we have 36 estates (or, real estate developments) in the *full sample* (and 26 in the *restricted sample*), there are more than 600 pair-wise correlations in returns and also in trading volume among estates for each "window" (2-year period). We calculate all of them and obtain a distribution of (sample) correlations. We then compute the mean, the standard deviation and the skewness of the distribution for each "window," and trace their evolutions over time. Interestingly, we find very clear and significant change in these moments, with the timing somehow later than the official date of the Asian financial crisis (based on the events in the foreign exchange market), suggesting a lag in response in the real estate market.[12] This change in correlations also confirms the causal observation of "a structural change" in the market. One of the virtues of the current approach is that it is intuitive and do not rely on any "bubble test", which can be controversial.[13]

There are obvious justifications for choosing Hong Kong in this study. First of all, the economic institution of Hong Kong is well developed, resulting in a higher efficiency level of the bureaucratic system and a lower corruption index.[14] Combining these with a fixed boundary,[15] a stable exchange rate, a simple tax system (no capital gains tax in particular), equal treatment for domestic and foreign investors, and no control on capital flows, foreign investors can enter the market anytime for arbitrage, should there be an under-pricing of real estate.[16] In addition, the real estate market of

[10] In Hong Kong, most housing transactions can be finished in a month. See Leung, Leong and Chan (2002).
[11] The results of *restricted sample* will be available upon request.
[12] For more discussion on Hong Kong during the Asian financial crisis time, see Kwan**,** Lui and Cheng (2001), Lui, Cheng and Kwan**,** (2003), among others.
[13] Clearly, the literature is too large to be reviewed here. Among others, see Gurkaynak (2008).
[14] Among others, see Acemoglu and Robinson (2006) for a discussion on why institutions are important.
[15] Due to the many agreements between the British and the Chinese governments, the boundary of Hong Kong is legally fixed and cannot expand, even after the turnover to the Chinese government. This is in sharp contrast to cities such as the larger L.A. or Houston, where geographical expansion is feasible.
[16] The exchange rate between Hong Kong and U.S. dollars has not changed since the mid-1980s.

Hong Kong is dominated by high-rise buildings with sufficient density of trading and an unusual degree of homogeneity. Other features of our dataset include the following: transaction-based rather than appraisal-based, estate-based rather than district-based, monthly frequency rather than quarterly, high-rise buildings, which are almost impossible to be extended, rather than detached houses. All these contribute to minimize the cross-sectional as well as time aggregation bias.[17]

Figure 1b plots monthly real residential property prices in the period 1992 M1-2005 M12. In these 14 years, there are a number of events that may be important in determining the value of residential housings, including the political uncertainty that given rise by arguments before the change of sovereignty in 1996, Asian Financial Crisis in 1997/98, the global technology (dot-com) stock meltdown in 2000, and outbreak of Severe Acute Respiratory Syndrome (SARS) epidemic in early 2003. It is not clear, however, whether the correlations among different estates should change with the aggregate housing price. Thus, this paper will test (1) does the correlation structure of housing price among residential estates display an asymmetric pattern over the cycle? And (2) Does the correlation structure of trading volume demonstrate a similar pattern as the real housing return?[18]

(Figure 1b about here)

The organization of this paper is as follows. The next section will provide a description of the data and the methodology. The results will be presented after that. The final section concludes and some technical details are reserved in the appendices.

2. Data Description

This section describes the data source, housing price variable and trading volume variables used in the proposed research. The dataset we are going to employ is provided by the Economic Property Research Center (EPRC), a subsidiary of the Hong Kong Economics Times. The EPRC purchased the data files from the Land

[17] For a discussion of the time aggregation bias, see Christiano and Eichenbaum (1987), Christiano, Eichenbaum and Marhall (1991). For a discussion of the cross-sectional aggregation bias, see Hanushek, Rivkin and Taylor (1996), among others.

[18] Leung, Lau and Leong (2002) also study the residential estates in Hong Kong and find that most estates display positively significant correlations among the detrended prices and corresponding trading volumes. An earlier version of this paper also explores whether the correlation structure demonstrates any contemporaneous segmentation of the residential property market. In other words, are there any substantial differences between within-group and inter-group correlations? The answer is negative, which seems to justify our current approach of investigation. The results are available upon request.

Registry Department of the Hong Kong Government and reorganized them in more readable format. Our sampling period starts from January 1992 and ends with December 2005, which is the longest time series available to us. This research focuses on the thirty-six large private residential estates (or sometimes called "complexes"), which are on the "*most frequently traded list*" of the EPRC dataset. Data files of these are complete. These estates exist at the beginning of the sampling period, which enables us to conduct the research in a balanced panel manner. They are listed in Table 2a. Totally there are almost 162,000 housing units, which is roughly 15% of all the private sector housing by 1992.[19] The respective final completion dates, the number of housing units the number of buildings, are also reported. Transaction records are grouped on a monthly basis. Following the literature, the measurement of the trading volume variable is simply the total number of housing units being transacted for each estate in each month.[20] As the trading volume series are non-stationary over time, the present study will "detrend" the variables by taking first difference. It avoids the problem of spurious correlation.

Our measure of "price" also follows a standard procedure. We use a hedonic pricing equation to "extract" the "quality controlled price series". In Hong Kong, several contracts need to be signed throughout the house purchasing process. To avoid the "double counting issue", only the data of the Agreement for Sales and Purchase (ASP) contract is employed.[21] As table 2b and 2c show, the selected estates cover a wide range of price, before or after adjusted for inflation, which will enable us to track the heterogeneous responses to a shock among different estates.

(Table 2a, 2b, 2c, 2d about here)

Since this paper studies how the correlations among the prices of different estates change over time, the measurement of the price deserve some serious attention. It is

[19] According to the official data, the total stock of private housing units is about 1.087 million by the end of 1991.

[20] Previous research on Hong Kong have shown that alternative measures of trading volumes produce very similar results for this period of time. Among others, see Leung, Lau and Leong (2002) for a discussion.

[21] In Hong Kong, as in many other places, several agreements need to be signed in the "transaction process". The other Contracts, such as Provisional Agreement for Sales and Purchase (P-ASP) and Assignment (ASSGT), are also included in the EPRC data. However, only the ASP contract, which is sometimes referred as "the final deal", is required to be signed by law in each transaction. Without ASP signing, the transaction is officially incomplete.

well known that a major obstacle to measure the housing price accurately is the intrinsic heterogeneity of housing units.[22] For instance, the composition of the properties being traded (such as large size versus size) may change over the business cycle. To control for the heterogeneity, this study follow the literature and adopted the hedonic pricing regression approach.[23] In addition, due to the unusual sample size, this study can afford to estimate the same hedonic pricing equation in each period, and thereby allowing for time-varying coefficients for different characteristics. It would provide a natural benchmark for us to compare the performance of the regression across different time periods.

Specifically, following the suggestion of Malpezzi (2002), a semi-log cross-sectional hedonic pricing equation in the following form is estimated for each month:

$$\ln \mathbf{P} = \beta_0 + \beta_1 \mathbf{S} + \beta_2 \mathbf{D} + \varepsilon$$

where ln P represents the natural log of the property prices, **S** represents structural traits (including the floor level, construction area of the apartment unit, the age of the building[24] and a dummy variable of lucky floor numbers), **D** represents a set of dummies (each one belongs to one estate)[25], ε represents the error term in regression, and β_I, I = 0,1,2, are the vector of coefficients obtained in each period t. We construct a constant-quality price index for each estate.[26] And since we intend to compare across different time series, we convert all the prices into real terms. The details of the index construction and variable definitions can be found in the Appendix.

Before the formal analysis, it is instructive to have an overview. As shown in figure 2a, the R^2 and adjusted R^2 of the hedonic pricing regression almost coincides each other, which suggests that there is no redundant variables on the right hand side. In fact, the hedonic pricing model seems to be "quite successful." On average, this simple model explains about ***91%*** of the housing price variations from 1992 M1 to 2005 M12. However, as also shown in figure 2a, there is a level drop for the goodness of fit (for both the R^2 and adjusted R^2) of this model in the later part of sampling

[22] Again, the literature is too large to be reviewed here. Among others, see Case and Quigley (1991), Quigley (1995), Englund, Quigley and Redfearn (1999).
[23] The literature is too large to be reviewed here. See Malpezzi (2002) for an extensive literature review.
[24] Squared and cubic terms of these three variables are also included in the equation, in order to capture any non-linear effect.
[25] (N -1) estate dummies will be included in the regression equation, where N is the number of estates that have transaction records in the period.
[26] See Berg (2004) for more details. The set of the independent variables for price calculation is chosen according to the mean value of housing attributes of the transactions in January 1992.

period (after the mid-1999). We employ the structural break test developed by Andrews and Ploberger (1994) and confirm that both the R^2 and adjusted R^2 experience *a break in August 1999*.[27] Also, the values of the R-square seem to become more volatile in the later period. We apply the structural break test again and for the month-to-month changes for both the R^2 and adjusted R^2, the estimated break-date is September 1999. Thus, it is about the *same time* that *the mean* R^2 *decreases and the variance of* R^2 *increases*. It may reflect a "structural change" in the housing market, such as a change of the market expectation.

(Figure 2a about here)

To further investigate the possibility of a "structural change" in the housing market, we follow the volatility decomposition procedure developed by Campbell, Lettau, Malkiel, and Xu (2001) (hereafter CLMX).[28] In the context of the stock market, CLMX attempt to decompose the volatility of individual stocks into the "market volatility" and the "idiosyncratic volatility." In a sense, this method is "model free." It does not require the researchers to estimate neither the betas (covariances) for individual assets, nor a highly parameterized time-varying volatility models. Details of CLMX "model-free" return decomposition can be found in the appendix.

In Figure 2b, we plot the time series of 24-month rolling window aggregate market variance (MKT), average estate-level variance (IDIO), and total variance (VAR) by giving equal weight on the 36 estates in our sample. Both the estate-level and the total variances start off relatively low and tend to rise towards the end of the period after the 1997 handover. The average idiosyncratic (estate-level) variance is the major component, contributing about ***73%*** of the total variance for the whole sample period. It is especially true in later years. While the share of idiosyncratic component only accounts for 60% of the total variation before 2001, the same ratio jumps to about ***92%*** of the post 2001 period! As in CLMX, a higher average idiosyncratic risk together with unchanged level of "market risk" implies a decrease in the mean correlation amongst the assets ("estates" in our case) in the portfolio. It is interesting to notice that the total variance and the share of idiosyncratic risk in the total variance

[27] The details are available upon request.
[28] The VOL correlation is not discussed in this section because the "fundamental" factor model is unsuitable to be borrowed to study the correlation between detrended trading volume.

move closely together. While it is premature to reach a conclusion with only figure 2a and 2b, they do suggest the possibility of a significant "structural change" in the housing market, which would be reflected in the correlation structures among different estates. This will be studied in much more details in the following sections.

(Figure 2b about here)

3. Methodology

This section explains the empirical tools used in the study. Since this paper follows the "rolling regression approach," two-year correlation coefficients are computed by rolling the sample period ahead one month at a time. Notice that these correlation coefficients are only sample moments and hence would change over time. They depend on which two-year period being selected. Thus, these correlation coefficients are regarded as random variables.[29] They are computed for each possible combination of pair of estates within each window (i.e. 630 for the full sample and 325 for the restricted sample). Clearly, this distribution of "sub-sample correlations" needs *not* be normal, or conforming to any well known cases. In fact, we will show that the distribution of the correlations change quite dramatically over time. It makes the complete tracking of the evolution of such distributions virtually impossible. To "summarize" the rich dynamics of the correlation distributions, we focus on the three moments, i.e. the mean, standard deviation and skewness of the distributions of all pair-wise correlation coefficients. Following the previous literature, we categorize the correlation coefficients into groups: (1) positive, (2) negative, (3) (statistically) significantly positive, (4) significantly negative for each window we estimate. The precise mathematical formulas are given in the appendix.[30]

[29] By construction, these correlations are likely to be strongly serially correlated, which tend to make "structural changes" less likely. As we will see later, however, structural changes do seem to happen in different places.

[30] In an earlier version of this paper, the asymmetry of correlation is also analyzed. Following the general estimation strategy (see Drobetz and Zimmermann, 2000), for a specific pair of residential estates, a month is classified as an "up-up" state if both estate returns are above their own average (positive semi-correlation), while a "down-down" state is defined as a month where both returns are less than their own average (negative semi-correlation). Correlations are separately estimated for the two regimes. Among other things, we find that pairs of estates which have positive correlation in returns within a certain window also tend to have positive correlation in trading volume, which may suggest those estates may be "substitutes" in that particular period of time. The details are available upon request.

4. Empirical Results

The empirical results are presented in the following order. First, an overview for the dataset will be presented. Then the rolling window technique will be used to compute the correlation coefficients for both detrended prices (or ROR) and trading volumes (VOL). It is followed by more diagnosis of the results.

4.1 Overview for the trading volume and Quality-Controlled Returns

Since the real housing prices are non-stationary over time, our analysis focuses on the returns, or the detrended housing prices, or simply *prices*. Table 2 has provided the summary statistics for the monthly, quality controlled, real rate of return for the 36 estates. In general, the standard deviation of real rate of return is high, reflecting considerable investment risk in the housing market. Table 3a and 3b provide the summary statistics for the monthly trading volume and detrended trading volume for the 36 estates in the sample (number of zero transaction months is included in Table 3a). An occasionally large number indicates there are typically primary sales for that estate in that month. Our restricted sample, with all the primary sales removed, however, produce essentially the same results. In other words, the dynamics of correlation structure, which is our focus of analysis, is somewhat robust to these outliers. For now, we will show how the correlation structure changes over time.

(Table 3a and 3b about here)

4.2 Rolling Window Estimation

4.2.1 Count of Correlation Coefficients in Each Window

Figure 3a shows how the compositions of different kinds of correlations among different estate detrended prices change over time. Clearly, the share of positive correlations (including both statistical significant and insignificant ones) is very large and not less than 64% throughout, which indicates the estates in the sample in general move in the same direction. However, there seems to be a structural break as the

percentage of positive correlations drops quickly since the 1999 M11. It means that there is a substantial difference in correlation structure between that month and 24 months ago. Clearly, there is significant overlapping between any two consecutive windows, as 23 out of 24 observations are identical. Thus, a structural change in correlation structure, which is confirmed by formal statistical test, is not likely to be driven by some outliers. Even when we restrict the attention to the share of significantly positive correlations, the structural break can still be found.[31] It started to drop at 1998 M6 with more dramatic speed than the share of positive correlations: it drops ***from around 90% in 1998 to just 10% in 2003***. Notice also that the "*speed*" the share of positive correlations *drop* seems to be much *faster than the increase*, and thus the correlation structure seems to be ***asymmetric*** in a sense. On the other hand, although the share of negative correlations increases up to more than 20% after 2000 M11, almost none of those negative correlations are significantly different from zero in the sampling period. So, the evidence suggests that the correlations among estate detrended prices (or, simply, *prices*) change from positive (i.e. co-move) to insignificant (i.e. un-correlated).

(Figure 3a, 3b about here)

Figure 3b shows the same kind of time plots for detrended trading volume in the *full sample*. As the case of detrended prices, the share of positive correlations is in general very large and not fewer than 67% throughout. And like the case of prices, the share of significantly positive correlations seems to exhibit some kind of "structural change" after the Asian Financial Crisis. It increases dramatically, and somehow persistently until the mid-1999. The share of the significantly positive correlations drops almost 30% in a single month! Again, the drop seems to be faster than the increase. On the other hand, although the share of negative correlations has increased up to 32% around the outbreak of SARS, most of the negative correlations are not significantly different from zero in the sampling period. In short, the pattern of the correlation structure for trading volume is very similar to that of prices.

4.2.2 The Summary Statistics of Correlation Coefficients

[31] The result is available upon request.

The previous analysis shows the composition change of the sample correlations. However, it does not give information about the magnitude of that change. Consider the following situation. Assume that there are 4 estates and totally 6 different pair-wise correlations. And for the argument sake, let us say 4 of them are 0.5 and the other two of them are -0.9. Clearly, the share of the positive correlations is 66%. However, the average correlation is only 0.03 and effectively zero. Thus, on top of calculating the share of significantly positive correlation, it may be important to calculate the moments (such as the average) of the distribution of correlations. Figure 4 provides a visualization of the mean of these real housing return correlations over time (solid blue line). And for comparison, we also provide the time plot of the value-weighted average of the sample price (dotted red line).

(Figure 4 about here)

The average correlation clearly displays an upward trend until the series reaches its peak value (from about 0.3 to more than 0.7) at 1998 M6, which covers the period from 1996 M7 to 1998 M6. It then experiences a sharp drop. As shown in the figure, the *decline in average correlation* somewhat *lags the drop of the average housing price*. The average correlation reaches its lowest point at 2003 M4, which is about 0.1.[32] The corresponding window covers the period from 2001 M5 to 2003 M4, which is the time of the SARS epidemic. Later, a number of supportive policy measures were introduced by the China Central Government and led to a recovery of the Hong Kong economy, including the housing market. It is especially true for some luxurious estates. Interestingly, the mean correlation does *not* rebound with the average housing price.[33] Clearly, the price correlations are highly non-stationary and cannot be easily analyzed with standard econometric tools such as VAR, VECM, which are more suitable for trend-stationary or first-difference-stationary type processes. Applying appropriate structural break tests will indicate that "breaks" do occur during the sampling period. Perhaps more importantly, this asymmetric relationship between the average correlation among different estate prices and the average housing price would

[32] It is not surprising that there are structural breaks in these series. Results are available upon request.
[33] In fact, we can confirm statistically that a structural break occurs in this series as well. The details are available upon request.

pose a challenge to theories which attempt to explain the housing price dynamics by aggregate shocks alone. By the same token, the continual process of sub-urbanization and improvement of transportation network *cannot* be an explanation for this "cycle" of mean correlation among the prices of different estates.

In the appendix, we also provide the counterpart for the standard deviation and the skewness. Interestingly, we find that the skewness of the distribution of correlations is like a mirror image of the mean correlation, with a correlation of *-0.95*. The distribution of correlations is generally negatively skewed (or called skewed to the left). We will have a "case study" in some later section. Now, we will turn to the correlation distribution for different estate trading volume.

Interestingly, the distribution of trading volumes displays a similar pattern as the prices. Figure 5 shows the mean of (detrended) trading volume in the *full sample* (solid blue line). For comparison, the 25-month sample rolling total trading volume is also included in the graphs[34]. First, the mean correlation of trading volume among different estates increases from slightly below 0.4 (1994 M1) to its peak, which is about 0.7 (1999 M1). Compared to the mean correlation for prices, the mean correlation of trading volume is a few months late in reaching its peak. A few months after January 1999, however, the mean correlation of trading volume experiences a sharp drop. In a month, the mean correlation almost loses all the "growth" accumulated in 5 years! It then fluctuates and has gone down to almost 0.1. In the later months, the mean correlation of trading volume restores to about 0.4, which is about the level at the beginning of the sample.[35] In the appendix, we also show the evolution of the standard deviation and the skewness of trading volume correlation distributions. And as in the case of price, the skewness of correlations among estates' trading volume is strongly related to the mean counterpart, with a correlation of -0.89!

(Figure 5 about here)

In addition, we have also calculated the correlation between the moment in price correlation and the trading volume correlation. It turns out that; not only price and

[34] Instead of plotting the series of monthly trading volume which is quite erratic throughout the sample period, we plot the 25-month sample rolling total trading volume. The 25-month rolling total is selected to keep the consistency of information set that used to compute rolling correlations of detrended volume.

[35] Not surprisingly, we can find statistical evidence of a structural break in this time series.

trading volume are correlated,[36] but also that these two-year moving-window correlations are also highly correlated. The correlation between mean price correlation and mean volume correlation is 0.87. The counterpart for standard deviation and skewness are 0.75 and 0.81 respectively, showing that price and volume are very deeply connected and it may worth the literature to further explore.

In sum, it seems that both in price and in trading volume, the mean correlation continues to increase from 1994 up to around late 1998 or early 1999, and then there is a dramatic decline. For trading volume, it eventually restores to the beginning level. For price, however, it goes down and stays at a "historical low" level. And while the mean correlations (for both price and trading volume) increase, the skewness measures of the correlation distribution become significantly more negative. And as the mean correlations collapse, so are the skewness measures.

4.2.3 Correlation Distribution in Two Selected Windows

The previous sections focus on some summary statistics to describe the evolution of the correlation distribution in both price and trading volume. To gain more insights on those distributions of correlations, this section selects two polar cases and examines in greater details how their corresponding distributions differ. Figure 6a and 6b show the frequency distribution of all pair wise correlations for *full sample* price (ROR) and volume (VOL) in two selected windows. They are the window with the highest average correlation in price (the 2 years period ends with 1998 M6) and that with the lowest average correlation (the 2 years period ends with 2003 M4). "Frequency" (or absolute frequency) in the vertical axis indicates the number of estate pairs while "Interval" in the horizontal axis assigns the correlation coefficients within the whole range of -1.00 to 1.00. It is interesting that the correlation distributions for price and trading volume are so similar.

(Figure 6a and 6b about here)

The first selected window covers the period 1996 M7 to 1998 M6, and the Asian financial crisis somewhat breaks out in between. Earlier in that period, there seems to

[36] It is widely documented. Among others, see Stein (1995).

be a market-wide factor which drives up the property prices in different estates to the same direction. Later the Asian Financial Crisis began in Thailand in July 2, 1997, with the collapse of Thai baht. During the subsequent months, international speculators attacked the Hong Kong Dollar, which was pegged at 7.8 to the US dollar. To defend the pegged exchange rate, the Hong Kong Monetary Authority lifts up the interest rate, resulting in a sharp slump in the equity markets. At the same time, the "85,000 policy" is announced by the former Chief Executive, Mr. Chee Hwa Tung, in his first Policy Address on October 8, 1997. He promises to provide affordable housing for the general public and to achieve a 70% homeownership rate. Thus, the increase in the interest rate and the expected increase in supply of affordable housing provided a market-wide adverse effect on the asset values.[37] And the housing prices in different estates decline together.[38] As expected, this window captures the period with the highest mean correlation of prices. In addition, as the correlation coefficients are bounded above by positive one, the distribution becomes more negatively skewed.

The second selected window covers the period 2001 M5 to 2003 M4, which is around the outbreak of SARS. As we can observe from Figure 6b, the distribution of correlation coefficients shows a lower average value, a larger standard deviation and an approximately symmetric shape, meaning that some of estate pairs are highly positively correlated while some of them are negatively correlated. There are a number of potential reasons for why the estates response differently to the shock during the outbreak of SARS. First, SARS has only a weak influence on the market-wide factor of property price determination. The estate-specific characteristics may still be the dominant factor. Second, while SARS brings a general downturn of the economy, the spread of the virus seems to be geographically concentrated.[39] Third, there is a sudden drop in transaction volume during April 2003 and the price measure may be "biased" by the "thin trading volume."

From the histograms, we are able to conclude that there is a coincidence of high average value, low standard deviation and high negative skewness in the correlation

[37] Ironically, after the housing price collapses, Mr. Tung abandoned the "85,000 policy" in June 2000. Among others, see Lau (2002) for the details.
[38] Among others, see Leung and Tang (2011).
[39] For instance, out of 1755 cases in Hong Kong, Amoy Garden alone accounts for 321 of them (about 18%). Medical staffs account for another 386 of them (about 21%). In order to prevent the spread of viral pneumonia, all residents in Block E of the Amoy Garden were moved by the HK government to a quarantine camp for ten days from 31 March 2003 to 9 April 2003. See Siu and Wong (2004) for more discussion.

structure of residential property market, for both (detrended) price and trading volume.

5. Further Evidence and Robustness

This section attempts to provide further evidence for a "structural change" in the correlations among different housing submarkets of Hong Kong, in order to establish the robustness of the results.

5.1. Volatility Decomposition and Correlation Distribution

This subsection attempts to connect the moments of the correlation distributions calculated in earlier section to the volatility decomposition developed by Campbell et al (2001), and applied to the Hong Kong market (results presented in section 2). Figure 7 displays the relationship between correlation and volatility components by plotting the ratio of IDIO to VAR, together with the mean correlation among the estate returns[40]. The mean correlation behaves almost like a *mirror image* of the ratio of the average estate-level variance to the average total variance, with a correlation between two series is about -0.99! This confirms similar findings in the previous studies of the financial market (for instance, see Kearney and Potì, 2004). The increase in the extent of the co-movement among different estate prices is associated with a decrease in the share of idiosyncratic volatility in the total volatility. Notice that the volatility decomposition method is developed for return but it is not clear how to apply to other variables, such as trading volume. On the other hand, this paper finds that the mean correlation series calculated from the rolling window method can capture basically the same phenomenon, and it can be applied to both return and trading volume. Perhaps future research can further explore this.

(Figure 7 about here)

5.2. Can the results be explained by composition change?

In the previous sections, we have adopted a "non-discriminating approach" in the computation of the mean correlations about housing returns and trading volume,

[40] See Kearney and Potì, (2004, 2006) for similar exercises on the European financial market.

meaning that we simply pool all 36 estates together in our calculation. It is possible, however, that those 36 estates actually come from different distributions. For instance, some of them may be "luxurious housing" while some are "normal housing." It is possible that the correlations within the same "class" do not change during a financial crisis, and yet the correlations among estates from different classes change significantly. In other words, the mean correlation calculation may be subject to some form of "composition bias." To investigate this possibility, we divide our sample into two groups, with the "luxurious group" consists of all estates in the Hong Kong Island, plus Parc Oasis and Village Gardens, and the "normal group" includes the rest of the estates. We find that whether we use the average total sale price as the criteria, or based on the previous research on Hong Kong housing market, or some subjective assessments in the media, we will obtain the same classification.[41] In the appendix, we show in details how the mean correlation can be interpreted as a weighted average of three sub-group mean correlations, which are S1 (the mean correlation within the luxurious group), S2 (the mean correlation within the normal group), and S12 (the mean correlation among the two groups, i.e. one estate is from the luxurious group and the other from the normal group). We apply the same procedure as before and Figure 8a, 8b show respectively the subgroup mean correlations for the housing returns and trading volume. Interestingly, the differences among the three subgroup mean correlations are very minor. This suggests that *our major results do not come from a composition change, but rather than there is an "universal change" in the mean correlation among estates*, whether within group or between group, and whether it is in terms of the returns or in terms of trading volume.

(Figure 8a, 8b about here)

5.3 A simple story for the empirical findings.

The previous subsections have examined in great details of the robustness of the empirical results. To close this section, this subsection attempts to give a simple story can account for all these "stylized facts." During the first sub-period (before the 1997),

[41] Among others, see Leung, Wong and Cheung (2007) for more details.

people all have good expectation of the market. The idiosyncratic component becomes relatively unimportant and its share in the total variance becomes smaller. At the same time, since the "market factor" is the driving force, there is a high correlation among estates in terms of price and trading volume. The Asian financial crisis then brings a "regime shift" in the expectation formation. People start to evaluate the estates according to individual characteristics. This leads to a sharp drop in the correlations among estates, and also a large increase in the share of idiosyncratic component in the total variance.

This "theory" is also consistent with the behavioral and experimental evidence presented by Thaler and Sunstein (2008). For instance, Thaler and Sunstein (2008, p.32) reported that in a survey of people starting new businesses, they were asked both the chance of success for a *typical business* and the counterpart of *their own business*. "The most common answers to these questions were 50 percent and 90 percent, respectively, and many said 100 percent to the second question." Thaler and Sunstein (2008, p.33) summarize that "Lotteries are successful partly because of unrealistic optimism. Unrealistic optimism is a pervasive feature of human life… if people are reminded of a bad event, they may not continue to be so optimistic." In the language of Wang et al (2002), people were "over-confident" when the house price is increasing and turned the other way round when they see the price "collapses."

Notice that while this explanation differs from the finance literature in at least one important dimension. Among others, Ang and Chen (2002), Connolly and Wang (2003), Longin and Solnik (2001), find that correlations among financial markets increase during market *downturns* than upturns. Recent theoretical works such as Veldkamp (2006), Yuan (2005) also generate similar predictions. In this *housing* market study, however, the average correlations among estates price (*trading volume*) *increase* with the average property price (*trading volume*), which is in sharp contrast to the case of the financial market.

6. Conclusion

While the media frequently used terms such as "structural change in the market," "bubble burst," etc., the academic literature has yet to reach a consensus for precise and operative definitions for these terms. This paper attempts to contribute to the literature by providing the Hong Kong experience as a concrete example of "structural

change in housing market." In particular, we estimate and analyze the time-varying correlation structure of real rate of return among the most frequently traded estates, and we find that the co-movements among different sub-markets vary significantly.

While our paper is empirical, it sheds light on several theoretical literatures. First, we find that in sharp contrast to the finance literature, however, the correlations among prices of different sub-markets are higher when the market booms. More specifically, the mean correlation of detrended prices increases from about 0.3 (1994 M1) to more than 0.7 (1998 M1). The Asian financial crisis then occurs and the real price of housing lost about half of its value in a few months. The mean correlation also goes down to below 0.2 (2001 M1), even before the SARS. The situation of mean correlation of trading volume is qualitatively similar but quantitatively more dramatic. It decreases from about 0.65 (1999 M1) to below 0.4 within a year! And even when both the detrended price and trading volume rebound after 2004 M1, the mean correlations stay low. These empirical findings clearly demonstrate real estate assets are indeed very different from the financial assets and more theoretical works are needed. Furthermore, the pattern of the price correlations and volume correlations among different sub-markets identified in this paper may not be easily explained by the family of theories which merely emphasize the aggregate shock, aggregate financial constraints or search frictions. It should be emphasized that existing theories have made important contributions for our understanding of the real estate markets in the "normal times." On the other hand, the "new stylized facts" provided by this paper focuses on the ability for those models to account for the markets in "crisis times." Obviously, future research efforts should be invested on building "*unifying framework*" which can account for *both* the "normal times" and the "crisis times."

On the other hand, our finding of "structural changes in price correlations and volume correlations" seems to be in line with recent theories which emphasize on the bounded rationality of agents. For instance, in Hong, Stein and Yu (2007), agents use oversimplified model to make their price forecast.[42] If one particular model performs poorly over a certain period of time, it will be replaced by another simple model, resulting in a "regime shift" in the forecasting. This is consistent with the Hong Kong experience before the Asian financial crisis, where housing investment is "always profitable," and the sudden change after that. The "over-confidence" theory put forth

[42] Clearly, it is beyond this paper to review the literature on "learning in finance". Among others, see Hirshleifer and Teoh (2003), Zhang (2006).

by Peng and Xiong (2006), among others, also help us to explain why the estate prices are so correlated and the "market factor" seems to dominate in the total variance before the crisis. In the context of financial market, Peng and Xiong (2006) show that if investors have limited attention, they *tend to process more market-wide information than firm-specific information*. If they are also overconfident, then the return correlations between firms can be higher than the fundamental correlations.

Our finding about "structural change" at the micro-level of the housing market in Hong Kong is also consistent with the research based on aggregate data. Among others, Chang et al (2011) find empirical evidence that the Hong Kong asset markets (i.e. the stock market and housing market) are influenced by the U.S. financial market variables and significant regime switching have been observed. Future works should try to relate the evidence at the micro-level and the aggregate-level in a unifying framework.

While this paper focuses on the Hong Kong experience, similar reasoning may also apply to other countries. For instance, Shiller (2008, p.28) states that the "housing bubble was a major cause, if not the cause, of the subprime crisis and of the broader economic crisis we now face. The perception that real estate prices could only go up, year after year, established an atmosphere that invited lenders and financial institutions to loosen their standards and risk default. Now the defaults are happening, massively and contagiously." Thus, to further test the hypotheses put forth by this paper is to wait for the end of the subprime crisis and see if the correlations among housing prices in different cities, or different districts within the same cities, actually decrease.

A weakness of this research is that we did not perform a formal statistical test on the "structural change." The confidence interval is the hard part. Notice that confidence interval is based on some assumptions of the underlying distribution. If the market, as a system, really experiences a structural change, then what is the appropriate distribution? Previous works on structural break tends to limit the attention to uni-variate case and the structural change of the variable to a very specific form and tests whether such form of break happens. Now it is a system that experiences a structural change, which will generate rolling-sample correlations among variables *within the system* that change from 0.35 to more than 0.7 (i.e. doubling). To the best of our knowledge, we are not aware of any work that describes this kind of structural change. We leave this to the future research.

Future research can also be extended in other directions. First, the sample can be enlarged. This thesis focuses on the most frequently traded list, which have transaction records as early as January 1992, in order to obtain the longest balance panel data. Future research may also extend to include the less frequently traded estates, or even other cities for comparison. Second, this research only focuses on the residential housing. Future research effort should extend to commercial real estate. Perhaps more importantly, a unifying framework should be built to nest both the case of financial assets (in which price correlation will decrease with the price) and the case of real estate studied here (in which price correlation will decrease with the price).

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Table 1 Summary of existing theory predictions

If the submarket co-movements are driven by…	*Pattern of co-movements among different submarkets*	*Reason*
(a) Aggregate shock and collateral constraint alone	**Constant over time or fluctuates around a constant**	**All submarkets face the same shock.**
(b) Search and Matching alone	**Constant over time or fluctuates around a constant**	**Degrees of search friction in different submarkets are constant over time.**
(c) Search and Matching; with loan preference over some submarkets by banks after a financial crisis	**Changes slowly**	**Search and Matching take time; the application and approval of loans also take time**
(d) investors who use over-simplified models and change models from time to time	**Dramatic changes of co-movements among submarkets can happen**	**When al agents switch from one model to another, dramatic changes in the asset price process can happen**

Table 2a List of Housing Estates

Estate Name	Completion Date	No. of Units	No. of Buildings
Hong Kong Island			
Beverly Hill	Dec-88	683	10
Chi Fu Fa Yuen	Jun-81	4326	27
City Garden	May-86	2393	14
Heng Fa Chuen	Nov-89	6311	48
Kornhill	Jun-87	6615	32
Lei King Wan	Feb-89	2295	17
Parkvale	Dec-89	838	4
Pokfulam Garden	Dec-79	1120	6
South Horizons	Mar-95	9232	34
Taikoo Shing	May-87	12690	61
Westlands Court	Jun-85	652	4
Kowloon Peninsula			
Amoy Garden	Jun-87	4896	19
Laguna City	Dec-94	8071	38
Mei Foo Sun Chuen	May-78	13063	99
Parc Oasis	Mar-95	1818	32
Sceneway Garden	Apr-92	4112	17
Telford Garden	Feb-82	4065	21
Village Gardens	Sep-87	488	53
Whampoa Garden	Jan-91	10287	88
The New Territories			
Allway Garden	Jun-81	3418	16
Belvedere Garden	Apr-91	6016	19
City One Shatin	Oct-87	10642	52
Fanling Centre	Dec-91	2200	11
Hong Kong Gold Coast	Mar-95	2052	30
Kingswood Villas	Dec-97	15836	58
Luk Yeung Sun Chuen	May-84	3624	16
Miami Beach Towers	Nov-91	1272	6
New Town Plaza	Jul-91	792	5
Riviera Garden	Dec-89	5636	20
Sea Crest Villa	Feb-95	2221	13
Serenity Park	Dec-94	2450	15
Sun Tuen Mun Centre	Sep-90	3407	10
Tai Hing Garden	Jan-94	3647	15
Tuen Mun Town Plaza	Sep-92	1928	8
Uptown Plaza	Apr-91	1200	6
Wonderland Villas	Aug-87	1502	22

Table 2b The Summary Statistics for the Monthly Nominal Housing Price (per square feet price in current HK dollars)

English Name	Max	Min	Mean	SD
Allway Garden	2961.6	896.5	1728.3	513.7
Amoy Garden	3836.5	1223.9	2330.4	646.4
Belvedere Garden	3791.9	884.5	2275.6	677.9
Beverly Hill	7400.2	944.6	4333.5	1020.5
Chi Fu Fa Yuen	4253.0	1429.2	2688.4	699.7
City Garden	5549.4	1644.6	3425.2	924.9
City One Shatin	3824.5	1180.6	2436.7	642.9
Fanling Center	4505.2	997.3	2050.3	616.8
Heng Fa Chuen	5596.4	1894.0	3328.7	880.9
Hong Kong Gold Coast	4380.5	808.5	2037.6	765.5
Kingswood Villas	2943.2	879.7	1624.4	469.9
Kornhill	5477.3	1714.2	3353.5	946.8
Laguna City	5068.0	1378.5	2939.1	931.9
Lei King Wan	5437.1	1787.3	3401.2	863.0
Luk Yeung Sun Chuen	4202.8	1331.6	2526.8	670.4
Mei Foo Sun Chuen	3851.1	1249.5	2236.3	611.3
Miami Beach	3851.7	987.6	1942.5	611.6
New Town Plaza	6555.5	1174.3	3790.3	1005.5
Parc Oasis	7414.0	2468.2	4262.6	1176.5
Parkvale	9213.6	1258.7	3344.5	990.2
Pokfulam Garden	4654.3	1385.9	2882.9	643.1
Riviera Garden	3854.3	1110.9	2249.6	688.6
Sceneway Garden	5322.7	1397.7	3129.3	994.6
Sea Crest Villa	5118.9	1081.5	2489.5	904.2
Serenity Park	3798.9	1331.6	2415.9	672.7
South Horizons	5048.9	1677.6	3039.9	750.0
Sun Tuen Mun Center	2707.0	760.1	1516.6	419.8
Tai Hing Garden	3621.1	894.9	1496.0	427.5
Taikoo Shing	5478.9	2012.4	3437.7	876.0
Telford Garden	4169.1	1308.1	2475.3	723.2
Tuen Mun Town Plaza	2756.2	889.3	1588.9	416.6
Uptown Plaza	4441.5	1264.1	2821.0	745.3
Village Garden	8682.4	1215.6	4514.1	1271.9
Westlands Court	5783.1	1261.7	2620.1	740.2
Whampoa Garden	5306.9	1770.4	3207.9	939.4
Wonderland Villas	5290.5	1010.3	3015.2	1028.0

Table 2c **The Summary Statistics for the Monthly Real Housing Price (per square feet price in 1992 M1 constant HK dollars)**

English Name	Max	Min	Mean	SD
Allway Garden	2961.6	896.5	1728.3	513.7
Amoy Garden	3836.5	1223.9	2330.4	646.4
Belvedere Garden	3791.9	884.5	2275.6	677.9
Beverly Hill	6994.8	944.6	4330.4	1006.0
Chi Fu Fa Yuen	4253.0	1429.2	2685.5	695.3
City Garden	5549.4	1644.6	3425.2	924.9
City One Shatin	3824.5	1180.6	2436.7	642.9
Fanling Center	3270.9	997.3	2040.4	589.9
Heng Fa Chuen	5596.4	1894.0	3331.4	884.5
Hong Kong Gold Coast	4380.5	808.5	2024.7	758.6
Kingswood Villas	2943.2	879.7	1624.4	469.9
Kornhill	5477.3	1714.2	3353.5	946.8
Laguna City	5068.0	1378.5	2939.1	931.9
Lei King Wan	5437.1	1787.3	3401.2	863.0
Luk Yeung Sun Chuen	4202.8	1331.6	2526.8	670.4
Mei Foo Sun Chuen	3851.1	1249.5	2236.3	611.3
Miami Beach	3851.7	987.6	1939.5	614.6
New Town Plaza	6555.5	1174.3	3789.4	1013.4
Parc Oasis	7414.0	2468.2	4262.6	1176.5
Parkvale	5169.5	1258.7	3284.1	852.2
Pokfulam Garden	4654.3	1385.9	2878.4	648.1
Riviera Garden	3854.3	1110.9	2244.6	682.5
Sceneway Garden	5322.7	1397.7	3129.3	994.6
Sea Crest Villa	5118.9	1081.5	2474.3	892.3
Serenity Park	3798.9	1331.6	2415.9	672.7
South Horizons	5048.9	1677.6	3039.9	750.0
Sun Tuen Mun Center	2707.0	760.1	1516.6	419.8
Tai Hing Garden	2521.1	894.9	1485.9	395.9
Taikoo Shing	5478.9	2012.4	3437.7	876.0
Telford Garden	4169.1	1308.1	2475.3	723.2
Tuen Mun Town Plaza	2756.2	889.3	1580.3	414.2
Uptown Plaza	4441.5	1264.1	2817.0	741.7
Village Garden	8682.4	2161.4	4589.5	1237.7
Westlands Court	4117.3	1261.7	2592.9	711.8
Whampoa Garden	5306.9	1770.4	3207.9	939.4
Wonderland Villas	5290.5	1010.3	3024.0	1030.3

Table 2d **The Summary Statistics for the Monthly Real Rate of Return (in percentage)**

English Name	Mean	Median	Maximum	Minimum
Allway Garden	0.108	7.728	25.021	-21.742
Amoy Garden	-0.067	5.379	25.812	-16.366
Belvedere Garden	0.128	7.846	62.820	-38.236
Beverly Hill	2.211	23.303	213.753	-77.062
Chi Fu Fa Yuen	0.118	6.679	20.011	-19.955
City Garden	0.639	11.164	54.083	-33.735
City One Shatin	0.018	5.568	24.759	-23.322
Fanling Center	-0.039	5.368	15.103	-18.177
Heng Fa Chuen	0.165	5.894	23.918	-21.606
Hong Kong Gold Coast	0.721	13.655	61.359	-35.981
Kingswood Villas	-0.148	5.113	14.001	-13.804
Kornhill	0.113	5.640	19.303	-17.688
Laguna City	0.140	6.939	30.542	-21.419
Lei King Wan	0.298	7.139	29.466	-25.016
Luk Yeung Sun Chuen	0.124	6.944	22.474	-20.275
Mei Foo Sun Chuen	0.151	5.085	14.669	-16.324
Miami Beach	0.162	7.938	26.083	-23.160
New Town Plaza	0.721	12.343	98.425	-46.725
Parc Oasis	0.536	9.340	42.755	-38.226
Parkvale	0.955	15.986	148.188	-56.109
Pokfulam Garden	0.954	13.869	64.133	-44.242
Riviera Garden	-0.018	6.295	28.067	-22.562
Sceneway Garden	0.249	7.177	24.193	-25.439
Sea Crest Villa	0.272	10.106	72.010	-27.359
Serenity Park	0.140	6.281	30.465	-19.592
South Horizons	0.227	5.568	12.187	-17.554
Sun Tuen Mun Center	-0.026	7.242	37.206	-19.247
Tai Hing Garden	-0.138	5.377	14.572	-15.882
Taikoo Shing	0.212	5.409	20.556	-12.992
Telford Garden	0.182	6.768	18.298	-19.699
Tuen Mun Town Plaza	-0.056	6.137	26.211	-22.139
Uptown Plaza	0.564	11.755	74.489	-46.256
Village Garden	1.947	20.520	132.262	-60.042
Westlands Court	0.145	7.873	28.664	-30.833
Whampoa Garden	0.021	4.681	17.193	-16.364
Wonderland Villas	0.350	10.337	58.620	-38.896

Table 3a The Summary Statistics for the Monthly Trading Volume

Estate Name	Mean	SD	Max	Min	No. of Zero Transaction Month
Allway Garden	19.375	12.671	76	1	0
Amoy Garden	38.905	23.813	128	7	0
Belvedere Garden	40.542	28.077	175	9	0
Beverly Hill	6.399	6.483	47	0	5
Chi Fu Fa Yuen	25.393	16.333	82	0	1
City Garden	15.357	9.979	62	3	0
City One Shatin	98.839	64.157	353	21	0
Fanling Center	18.970	14.046	74	0	1
Heng Fa Chuen	46.601	34.539	157	0	1
Hong Kong Gold Coast	10.988	16.526	149	0	2
Kingswood Villas	174.083	232.075	1267	14	0
Kornhill	47.548	33.625	183	7	0
Laguna City	71.738	78.447	624	11	0
Lei King Wan	15.821	10.628	48	2	0
Luk Yeung Sun Chuen	22.964	14.953	69	1	0
Mei Foo Sun Chuen	96.423	55.830	341	26	0
Miami Beach	12.446	10.032	64	0	1
New Town Plaza	5.327	4.418	25	0	8
Parc Oasis	21.077	36.902	343	1	0
Parkvale	5.131	4.110	19	0	6
Pokfulam Garden	7.167	4.666	27	0	3
Riviera Garden	37.280	27.428	156	0	1
Sceneway Garden	31.792	22.283	123	5	0
Sea Crest Villa	28.673	49.680	338	0	3
Serenity Park	25.690	27.208	218	3	0
South Horizons	99.899	169.510	1205	17	0
Sun Tuen Mun Center	24.649	17.436	97	4	0
Tai Hing Garden	36.911	67.538	693	0	1
Taikoo Shing	86.976	55.422	298	20	0
Telford Garden	26.304	16.094	99	7	0
Tuen Mun Town Plaza	16.000	19.786	180	0	1
Uptown Plaza	9.524	6.507	38	0	1
Village Garden	4.179	3.513	20	0	9
Westlands Court	5.607	4.460	21	0	5
Whampoa Garden	76.185	50.801	302	10	0
Wonderland Villas	11.155	9.246	52	0	1

Table 3b The Summary Statistics for the Detrended Monthly Trading Volume

Estate Name	MEAN	SD	Max	Min
Allway Garden	-0.036	11.392	48	-40
Amoy Garden	-0.341	22.305	81	-96
Belvedere Garden	-0.425	25.192	126	-118
Beverly Hill	-0.072	6.793	40	-39
Chi Fu Fa Yuen	-0.078	15.602	57	-55
City Garden	-0.198	8.800	25	-44
City One Shatin	-1.072	54.586	218	-208
Fanling Center	-0.024	10.445	37	-28
Heng Fa Chuen	-0.557	27.835	98	-102
Hong Kong Gold Coast	-0.036	15.954	100	-137
Kingswood Villas	-1.222	239.866	1217	-1138
Kornhill	-0.623	28.829	105	-131
Laguna City	-1.856	93.052	578	-572
Lei King Wan	-0.036	9.312	34	-28
Luk Yeung Sun Chuen	-0.293	11.924	38	-47
Mei Foo Sun Chuen	-0.707	47.336	207	-224
Miami Beach	-0.066	9.015	40	-43
New Town Plaza	-0.084	4.047	12	-16
Parc Oasis	-0.796	49.886	325	-310
Parkvale	-0.024	3.939	13	-13
Pokfulam Garden	-0.072	4.890	17	-12
Riviera Garden	-0.431	23.531	101	-82
Sceneway Garden	-0.102	17.288	57	-57
Sea Crest Villa	0.036	45.931	301	-274
Serenity Park	-0.060	24.557	201	-151
South Horizons	0.066	191.036	1161	-974
Sun Tuen Mun Center	-0.180	15.259	58	-68
Tai Hing Garden	0.060	72.845	692	-409
Taikoo Shing	-0.844	45.793	160	-190
Telford Garden	-0.275	14.784	57	-64
Tuen Mun Town Plaza	-0.036	20.158	163	-166
Uptown Plaza	-0.048	6.347	21	-25
Village Garden	0.000	3.706	13	-16
Westlands Court	-0.102	4.716	18	-15
Whampoa Garden	-0.647	40.751	139	-200
Wonderland Villas	-0.060	7.724	23	-38

Figure 1a Quarterly Housing Price Indices (Official Data; in real terms) (1999 Q1=100)

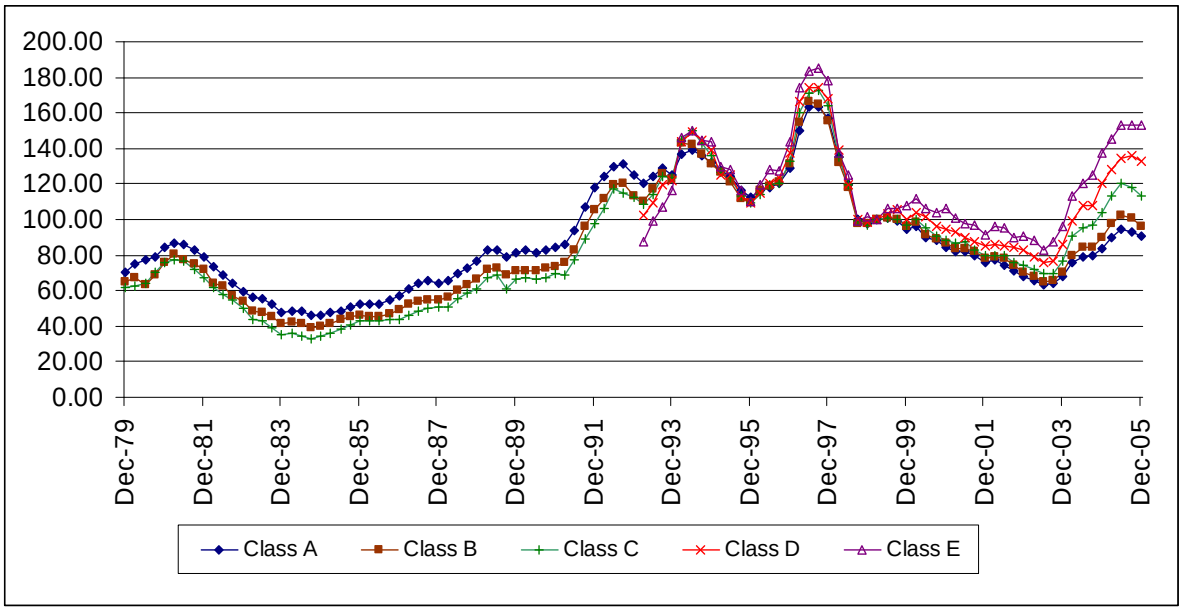


Figure 1b The Time Plots of Real Housing Price (Authors' calculations) (Jan 1993 =100)

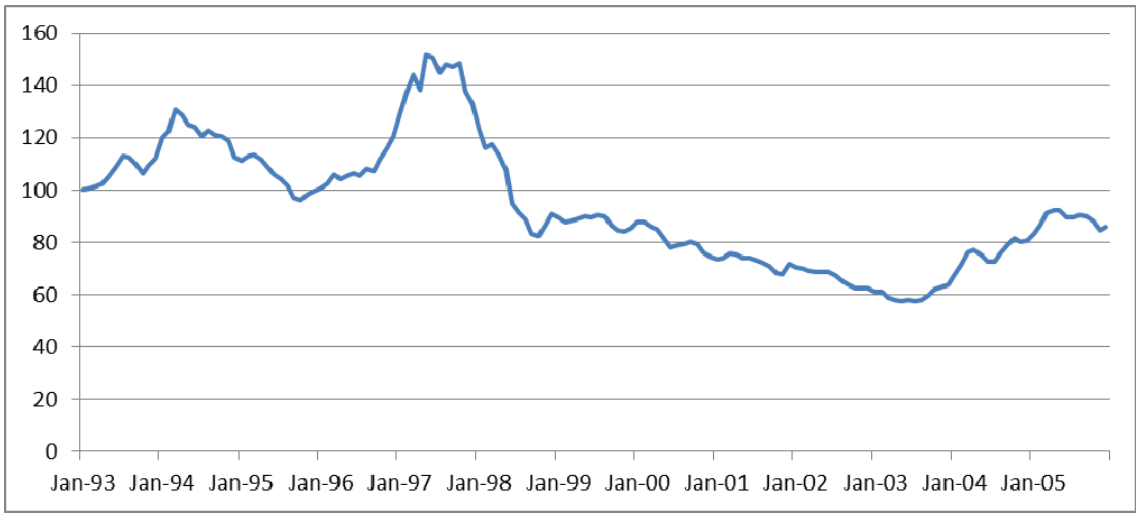


Figure 2a The Time Plots of Goodness of Fit of the Hedonic Pricing

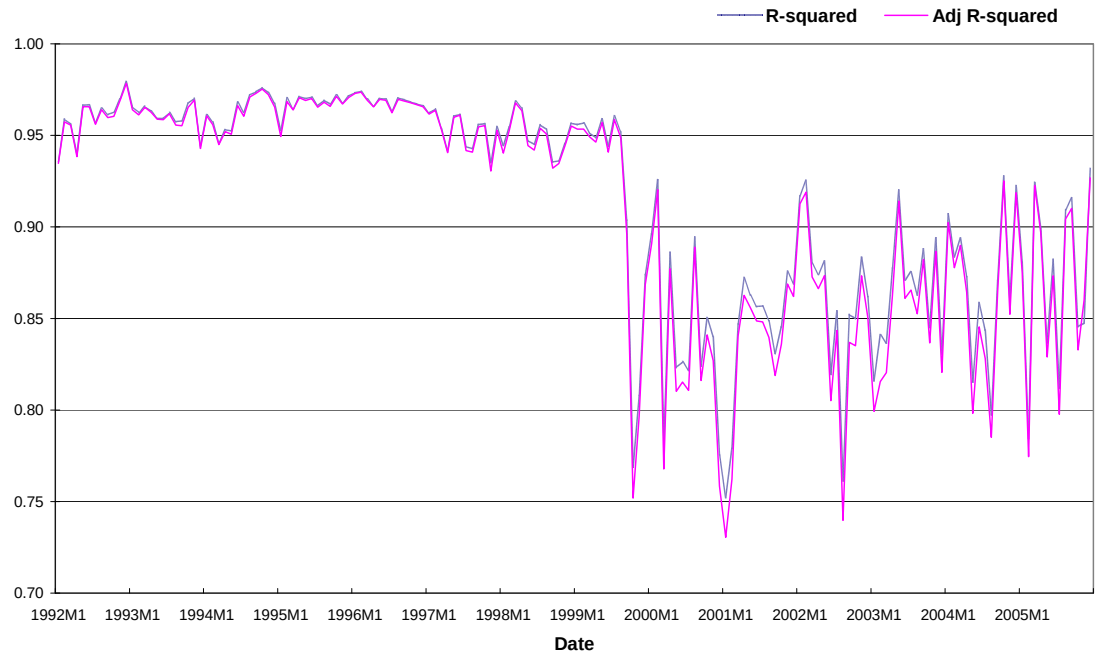


Figure 2b Aggregate Market Variance, Estate-Level and Total Variance - Full Sample

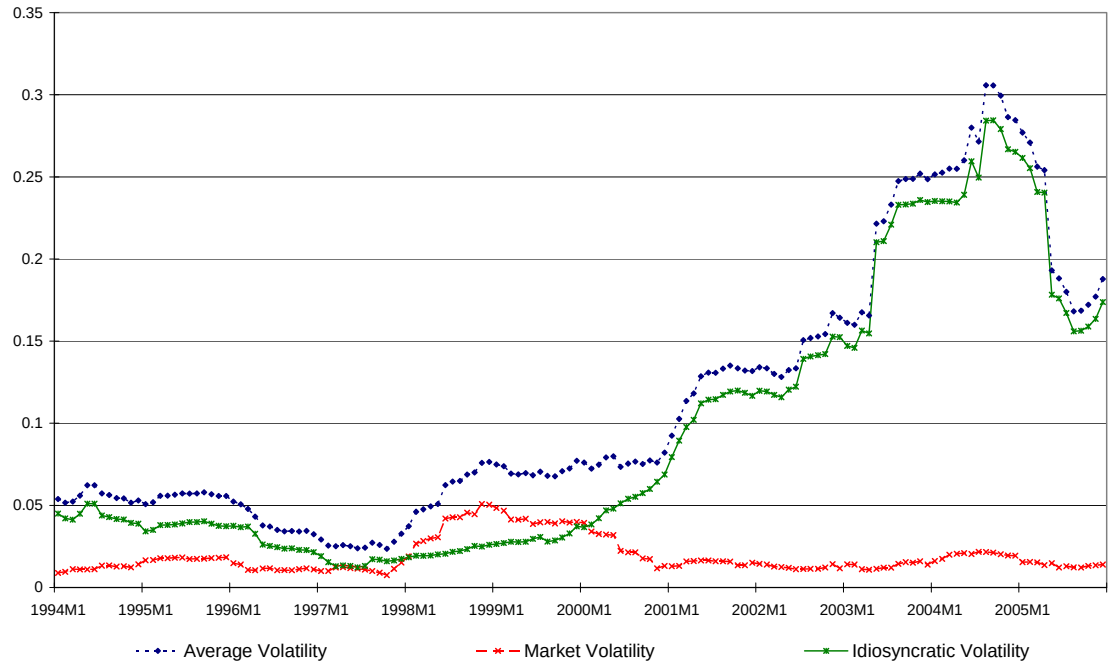


Figure 3a Count of Correlation Coefficients in Each Window for Full Sample Price

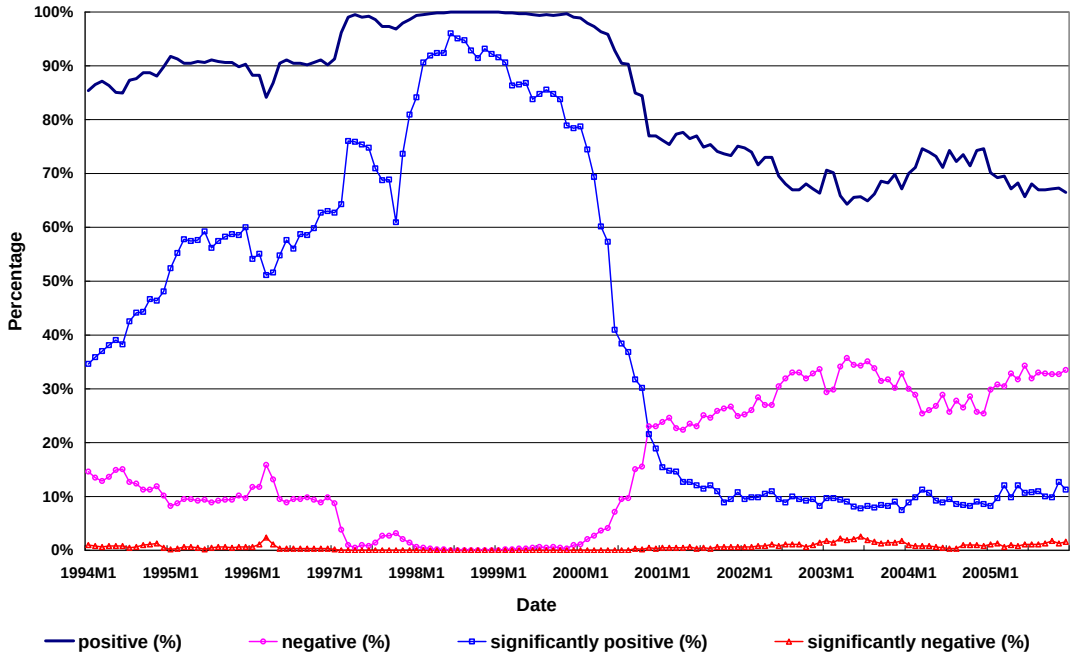


Figure 3b Count of Correlation Coefficients in Each Window for Full Sample VOL

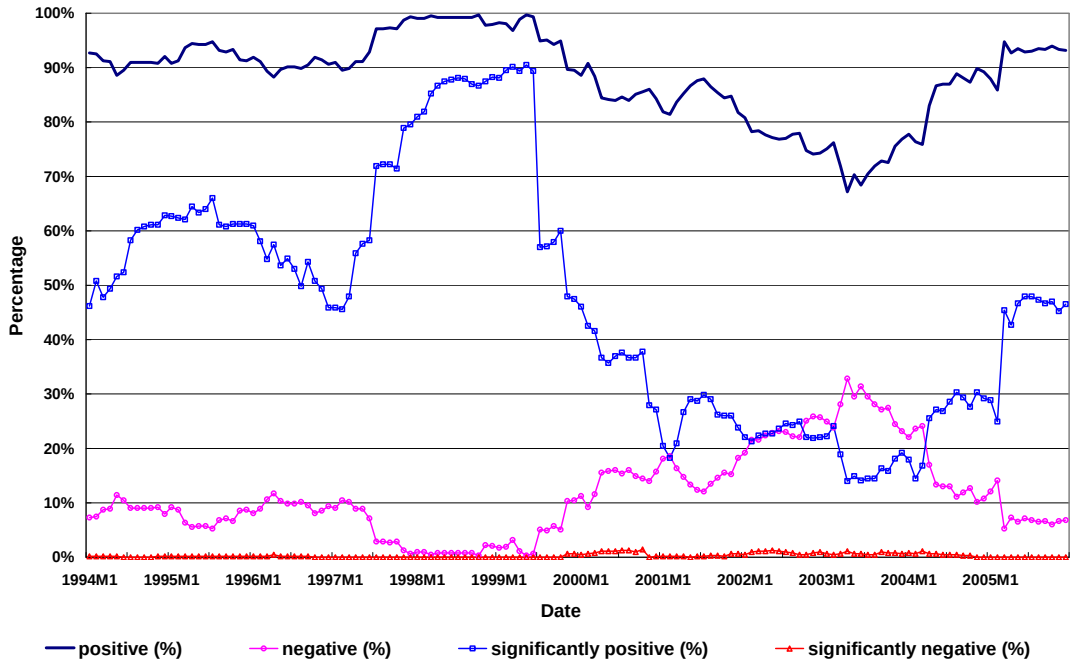


Figure 4 Mean - Rolling Window Correlation Coefficients for Full Sample Price

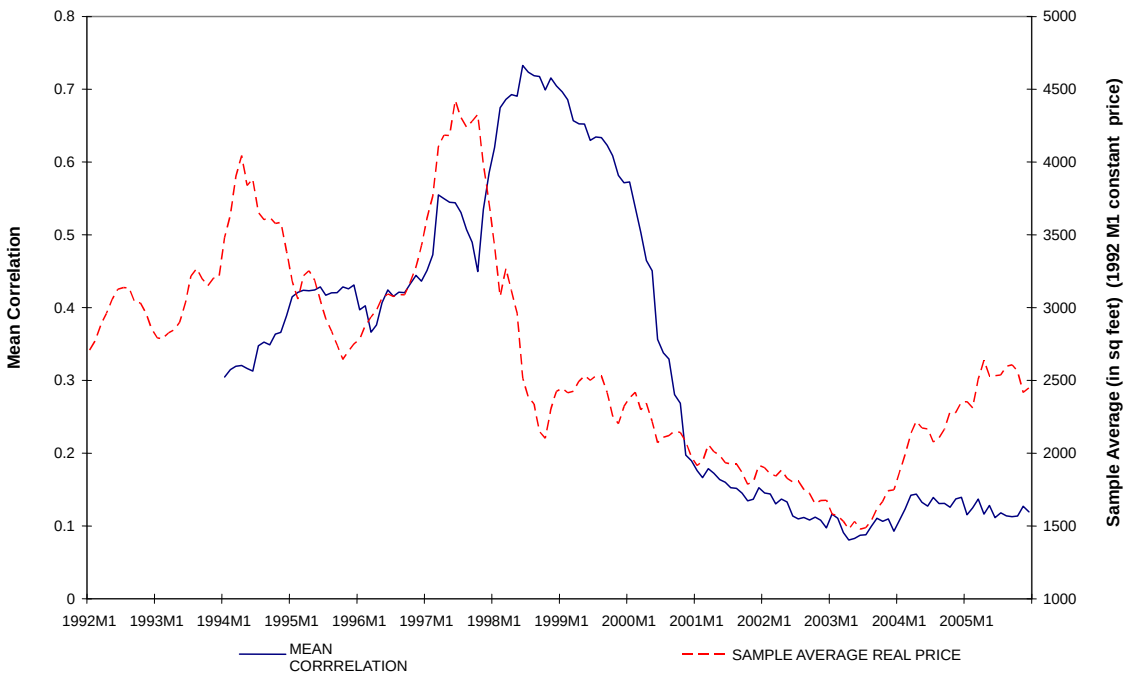


Figure 5 Mean - Rolling Window Correlation Coefficients for Full Sample VOL

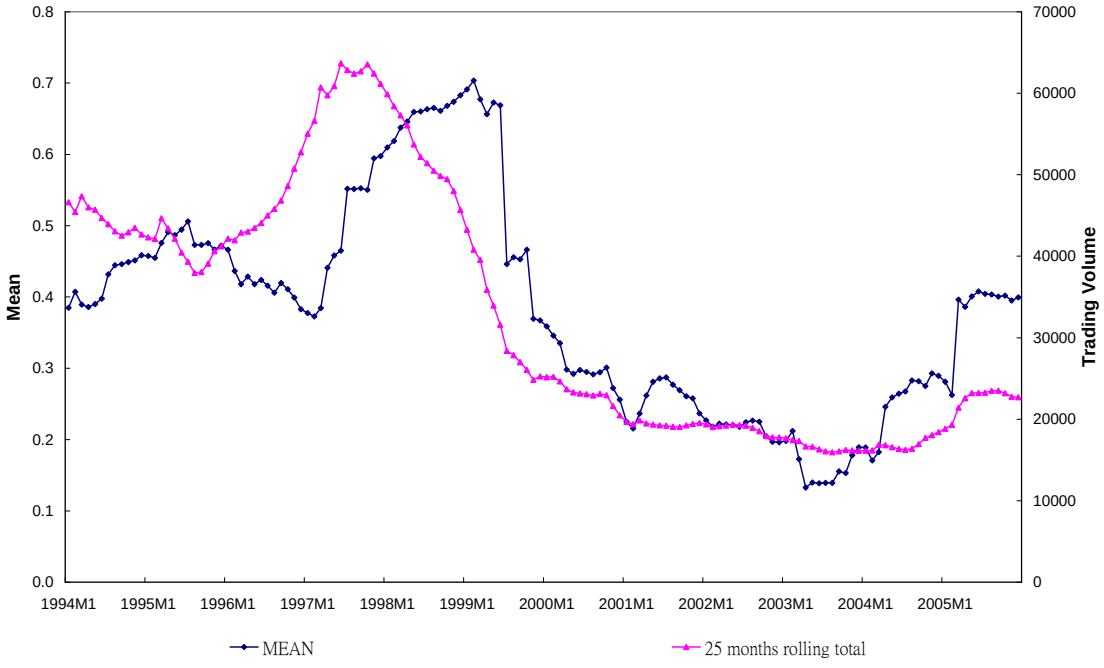


Figure 6a Distributions of Correlation Coefficients During the Most Correlated and the Least Correlated Periods - Full Sample Price (ROR)

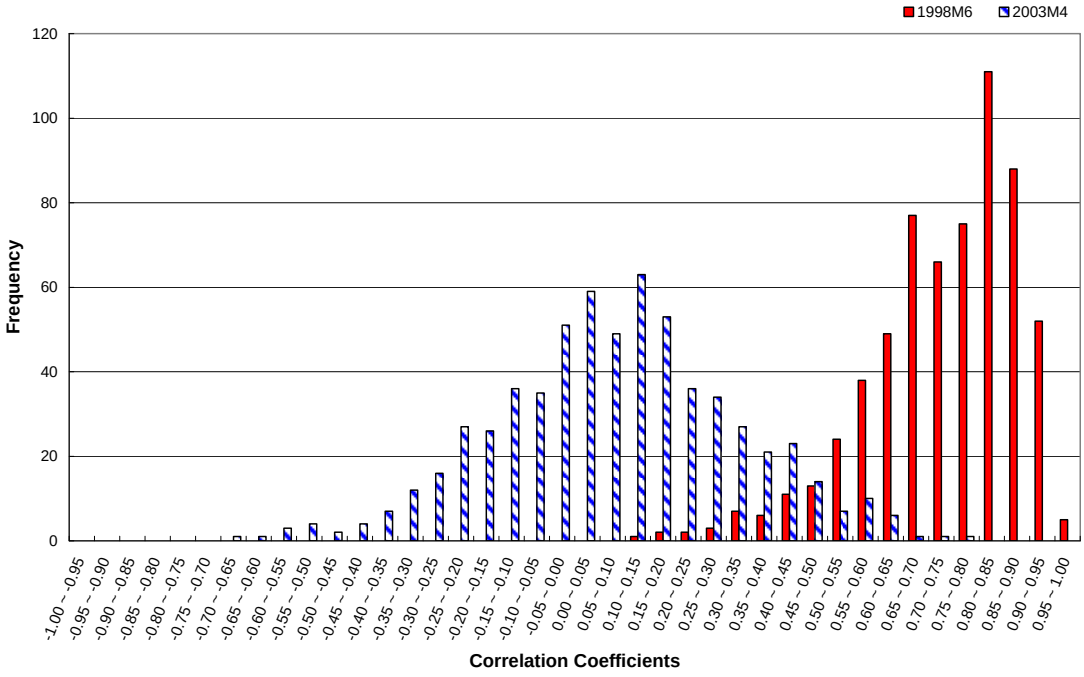


Figure 6b Distributions of Correlation Coefficients During the Most Correlated and the Least Correlated Periods - Full Sample VOL

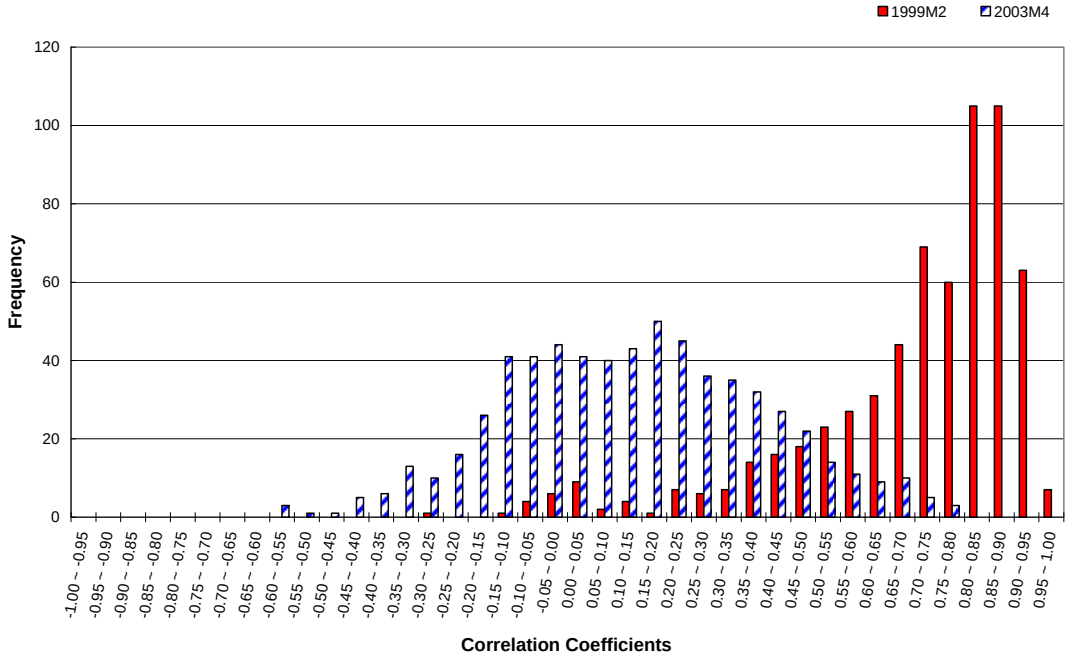


Figure 7 Variance Ratio and Mean Correlation - Full Sample

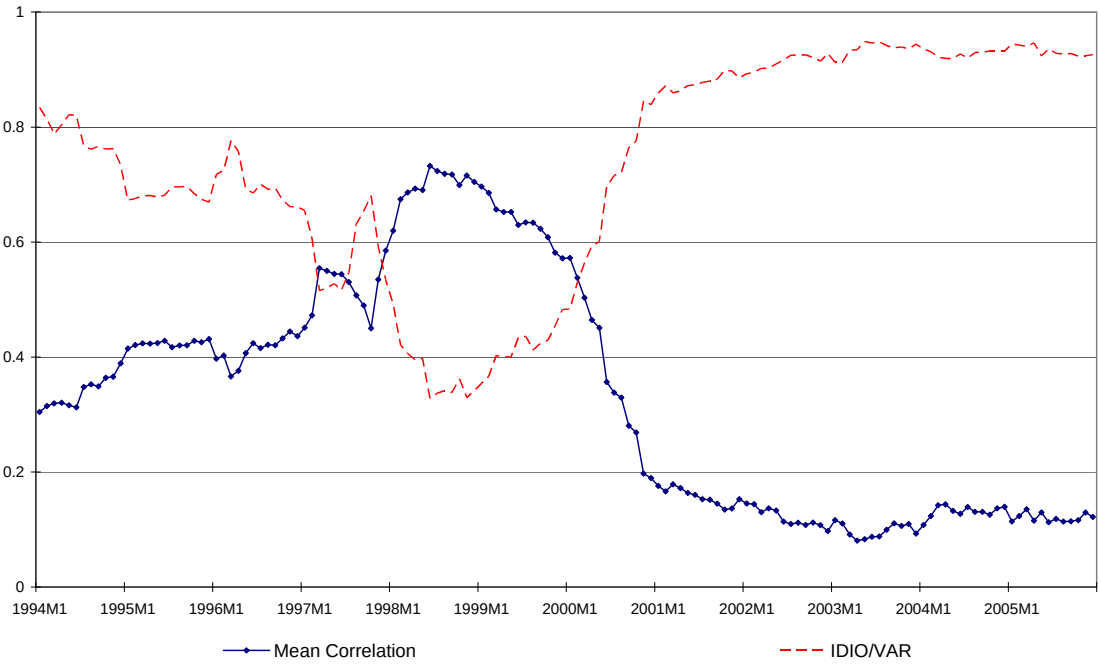


Figure 8a Decomposition of the mean correlation of returns among different estates.

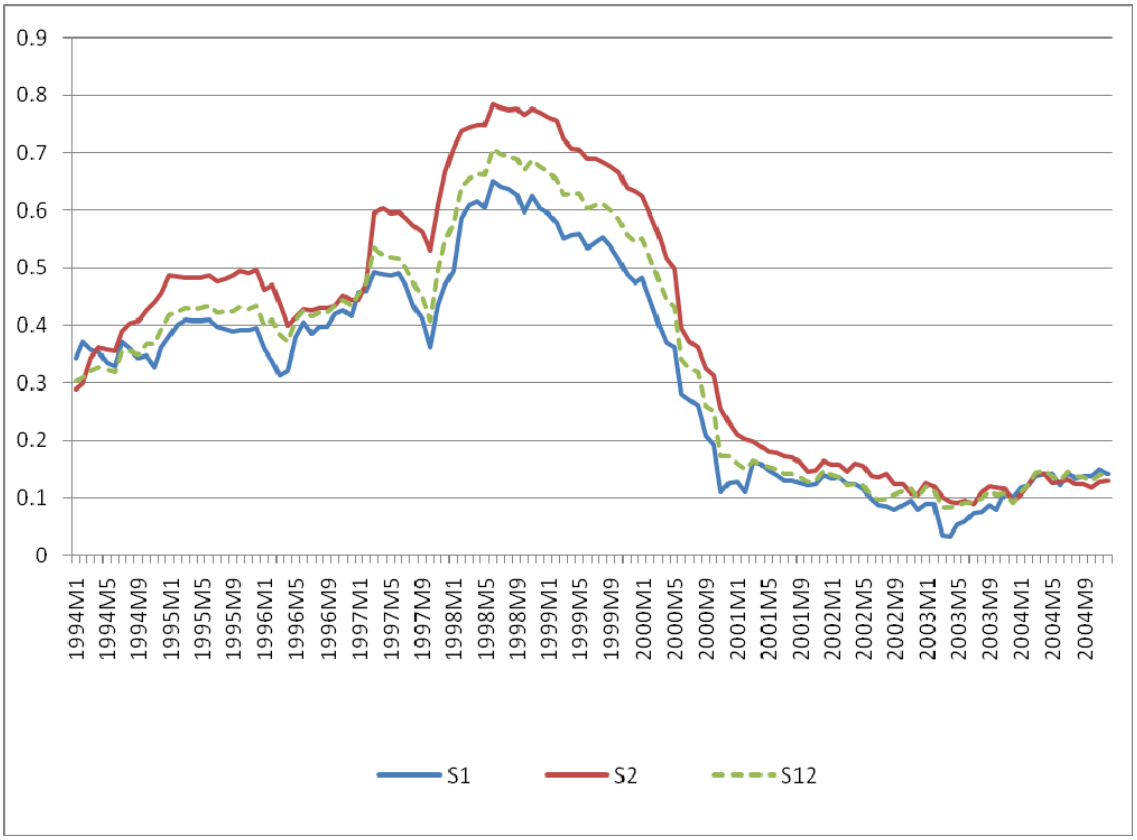
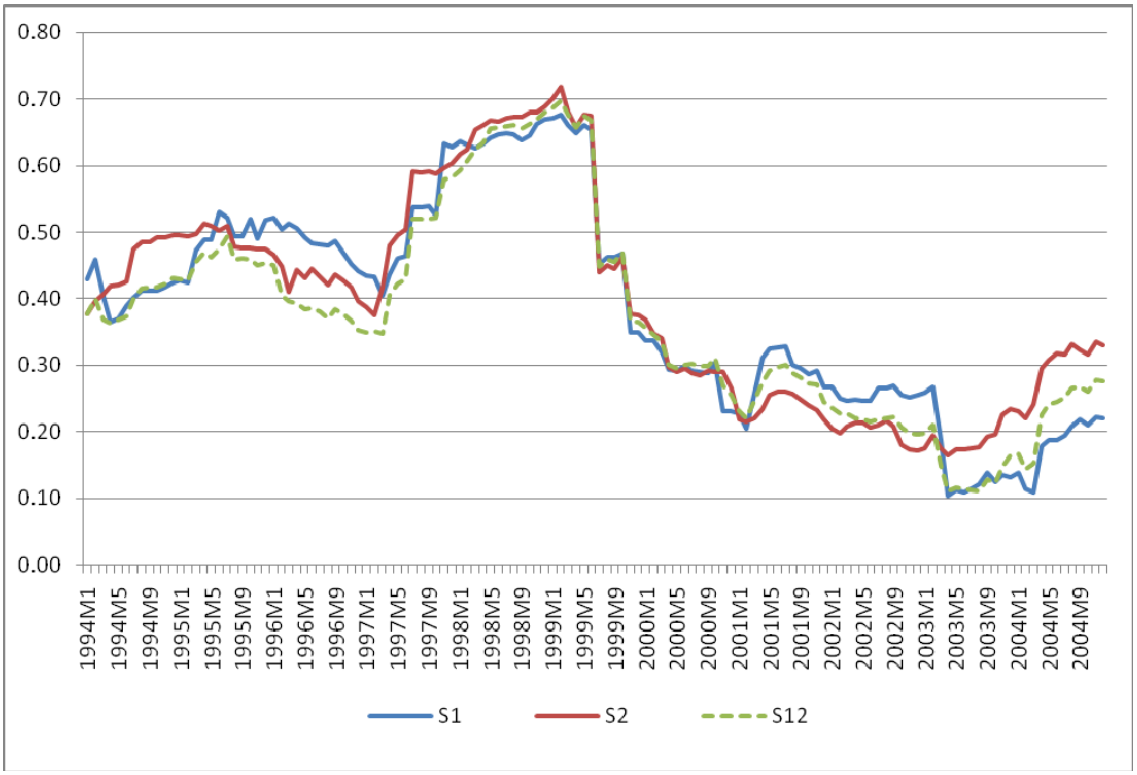


Figure 8b Decomposition of the mean correlation of trading volumes among different estates.



Appendices

Appendix I

A Summary of Hedonic Pricing Equation

In our hedonic pricing models, a number of variables were used to capture both the within-estate and intra-estate heterogeneity.

1. Within-estate Variables

All housing units in our sample are selected from large 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 (measured in square feet)[43], and building age (time distance between the date of completion and date of our investigation)[44] to capture the within-estate variation. Squared and cubic terms of these three variables are also included in the equation, so to capture any non-linear effect. Also a dummy variable of lucky numbers (a flat is located on a floor with lucky numbers (i.e. 8,18,28 and 38)) is included to capture the possible effect of this cultural factor, which is a concern (in terms of "feng shui") that may be of particular importance in the Chinese context.

2. Intra-estate Variables

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 our primary goal is to investigate the time-varying correlation structure of the residential property market, we have to maintain the uniqueness of price dynamics of each estate in our sample. However, traditional approach of introducing neighborhood attribute variables such as swimming pools, proximity to waters, proximity to local, mass transportation (i.e. subway or train stations), district-level measures (i.e. Hong Kong Island, Kowloon Peninsula, or the New Territories) is inappropriate as some of the pairs of estates share exactly the same set of 'observed' characteristics (e.g. Village Garden and Parc Oasis). This necessarily implies that their returns that based on the hedonic-constructed indices will share the same dynamics. In order to prevent this situation, we decide to replace all these attributes by a set of dummy variables that each one represents one estate.

In addition, we convert all nominal prices into real ones by deflating the nominal prices by the Consumer Price Index (A) (Year 1992=1).

The 'outlier' problem can be troublesome in all real estate market studies. There are quite a number of transactions that house prices that seems to be far away from expected,

[43] The EPRC provides two numbers of area data: the gross area and the net area. In this study we have picked the gross area. The first reason is that information on the net area is not always available. The second reason is that we want to avoid the potential source of measurement error in the sample. In Hong Kong, there is neither official regulation nor professional consensus about how to measure the net area. Consequently, the "net area" reported by property developers is subject to personal bias and varies between developers.

[44] This specification will make the index construction procedure, which based on the parameters of hedonic pricing models, more efficient.

with respect to the recorded attributes of the housing units. However, casual exclusion of the potential outliers could be risky in creating biases in index construction, if we eliminate too many observations. Huge amount of effort has to be made to check or correct every suspicious case and to avoid incorrect exclusion and this will not be feasible when we handle a huge dataset. As a result, we decide to adopt a relatively operational approach, i.e. removing those transaction records with real per-square-feet price lower than $100 in the stage of estimating the hedonic pricing model.

For luxurious estates, it is almost unavoidable that there are a number of months which do not any transaction, as their market is relatively thin. Following the practice of past studies, the price of the zero-transaction month is set equal to the transaction price of previous month. This treatment is intuitive because the real rate of return is perceived to be zero when there is no transaction record during the month. In addition, as the residential property prices are non-stationary over time, the present study employs the (realized) rate of return, which is defined as the monthly percentage change of real price. This can sometimes be regarded as the detrended property price (See Leung, Lau and Leong (2002)). In addition, this practice can also help to eliminate the possible scale effect.

Appendix II

Details Results regarding the Trading Volume

As we circulate our paper, many have shown concerns about the results on the trading volume. To ease those concerns, we show the detailed results on the trading volume here.

Stationarity of Trading volume

Estate	Is TV stationary?	Is the first difference of TV stationary?
HK Island		
Beverly Hill	No	Yes
Chi Fu Fa Yuen	No	Yes
City Garden	No	Yes
Heng Fa Chuen	No	Yes
Kornhill	No	Yes
Lei King Wan	No	Yes
Parkvale	No	Yes
Pokfulam Garden	No	Yes
South Horizons	No	Yes
Taikoo Shing	No	Yes
Westlands Court	No	Yes
Kowloon Peninsula		
Amoy Garden	No	Yes
Laguna City	No	Yes
Mei Foo Sun Chuen	No	Yes
Parc Oasis	No	Yes
Sceneway Garden	No	Yes
Telford Garden	No	Yes
Village Gardens	No	Yes
Whampoa Garden	No	Yes
New Territories		
Allway Garden	No	Yes
Belvedere Garden	No	Yes
City One Shatin	No	Yes
Fanling Centre	No	Yes
Hong Kong Gold Coast	No	Yes
Kingswood Villas	No	Yes
Luk Yeung Sun Chuen	Yes	Yes
Miami Beach Towers	No	Yes
New Town Plaza	No	Yes
Riviera Garden	No	Yes
Sea Crest Villa	Yes	Yes
Serenity Park	No	Yes
Sun Tuen Mun Centre	No	Yes
Tai Hing Garden	Yes	Yes
Tuen Mun Town Plaza	No	Yes
Uptown Plaza	No	Yes
Wonderland Villas	No	Yes

Note: ADF test is used to check the stationarity of trading volume at 5% significance level (with lag = 12). Its form is:
$\Delta Y_t = \alpha + \beta T + \delta Y_{t-1} + \gamma_i \sum \Delta Y_{t-i} + u_t$
The null hypothesis is that $\delta = 0$, in which a unit root exists in the time series of Y. If the t-statistics is greater than the ADF critical value, we cannot reject the null, which implies Y is

not stationary.

Our impression is that, for several estates, the "non-stationarity" comes from a few months of un-usually high trading activities. That will be the case for Hong Kong Gold Coast, Sea Creat Villa, Tai Hing Garden, Tuen Mun Town Plaza, etc. In some other estates, they simply have more trading activities before 1997. Once we take the first difference, these differences are harmonized and hence become stationary.

Appendix III

A Summary of Calculating Correlation Coefficient

Statisticians measure and describe the degree of linear dependence between events (or variables), or how closely they co-vary, by means of a statistic called the correlation coefficient. A correlation coefficient can have a value from -1 to 1. A correlation coefficient of 1 (-1) means that there is a perfect positive (negative) linear relationship between the two variables. A correlation coefficient of 0 means that there is no linear relationship between the variables.

A correlation coefficient describes only the overall (or average) degree of linkage between two events in a static way. This measure does not reveal whether the degree of linkage remains stable over time, or whether linkages change under extreme or unusual conditions. And so, the two following techniques try to add the time-varying property into this commonly used statistic.

1. Rolling Window Estimation

Let x_i be the realized value of real rate of return (or detrended trading volume) for residential estate x on month *i*, at a backward-looking window (length = 24 months) in time *t* (this date refers to end of 24-month window),

$$\text{Sample Mean} = \overline{x_t} = \sum_{i=0}^{23} x_{t-i}$$

$$\text{Sample Variance} = S_x{}^2 = \sum_{i=0}^{23} (x_{t-i} - \overline{x_t})^2 / (24-1)$$

$$\text{Sample Covariance} = S_{xy}{}^2 = \sum_{i=0}^{23} (x_{t-i} - \overline{x_t})(y_{t-i} - \overline{y_t}) / (24-1)$$

$$\text{Sample Correlation} = C_{xy} = S_{xy} / (S_x S_y)$$

The count of correlation coefficients that are (1) positive, (2) negative, (3) significantly positive and (4) significantly negative; the summary statistics (including mean, standard deviation and skewness) and the frequency distribution will be based on the estimated sample correlation (C_{xy}) of 630 *(325 for restricted sample)* (i.e. N(N-1)/2) pairs of residential estates.

Appendix IV

CLMX Variance Decomposition

Here we present the CLMX (2001) "model-free" return decomposition that applicable in our study for Hong Kong residential property market. In a standard single-factor CAPM framework with a zero risk-free rate, estate *i*'s excess return in period *t* can be expressed as:

(1) $$R_{it} = \beta_{im} R_{mt} + \widetilde{\varepsilon}_{it}$$

where β_{im} is estate *i*'s sensitivity to the market return (R_{mt}) and $\widetilde{\varepsilon}_{it}$ is the portion of the return that is uncorrelated with the market portfolio (i.e., orthogonal to R_{mt} by construction). The variance of equation (1) divides the total risk of estate *i* into market and estate-specific component.

(2) $$Var(R_{it}) = \beta_{im}^2 Var(R_{mt}) + Var(\widetilde{\varepsilon}_{it})$$

Decomposing the variance in such ways will require us to estimate estate sensitivities to the whole market (β_{im}). CLMX variance decomposition is a clever method that gets around the necessity to estimate the beta coefficients by imposing the assumption of unit market betas (i.e. $\beta_{im} = 1$ for all *i*). In this way, we can just focus on the weighted average variance across residential estates. In this simplified framework, the return for estate *i* is expressed as:

(3) $$R_{it} = R_{mt} + \varepsilon_{it}$$

Substituting in for R_{it} from equation (1) and solving for the estate-specific residual ε_{it} yields:

(4) $$\varepsilon_{it} = (\beta_{im} - 1) R_{mt} + \widetilde{\varepsilon}_{it}$$

Noting that $Cov(\varepsilon_{it}, R_{mt}) = Cov((\beta_{im} - 1) R_{mt} + \widetilde{\varepsilon}_{it}, R_{mt}) = (\beta_{im} - 1) Var(R_{mt})$, the variance of R_{it} in (3) may be expressed as:

(5) $$\begin{aligned} Var(R_{it}) &= Var(R_{mt}) + Var(\varepsilon_{it}) + 2Cov(R_{mt}, \varepsilon_{it}) \\ &= Var(R_{mt}) + Var(\varepsilon_{it}) + 2(\beta_{im} - 1) Var(R_{mt}) \end{aligned}$$

which reintroduces the beta coefficients into the simplified variance equation. As mentioned by CLMX, since the weighted average of all betas equals one, taking the weighted average across all estates will make the last term on the right-hand-side collapse to zero. Finally, it yields a beta-free decomposition of average estate volatility[45]:

(6) $$\sum_i w_{it} Var(R_{it}) = Var(R_{mt}) + \sum_i w_{it} Var(\varepsilon_{it})$$

where w_{it} is estate *i*'s market weight at time *t*.

For simplicity and easier interpretation (because throughout the paper, the market ROR correlation is taken to be a simple average of all pair wise correlation coefficients), we assume that we have an equally-weighted market portfolio, i.e. $w_{it} = 1/n$, where n is the number of residential estates in the portfolio[46]. And consequently the left-hand-side will be the average total volatility (hereafter **VAR**) and the right-hand-side will consist of two components: the market volatility (hereafter **MKT**) and the average estate-specific volatility

[45] This decomposition is only an approximation as pointed out by CLMX (2001) because the average estate-specific volatility (IDIO) is only approximately equal to the average variance of the CAPM idiosyncratic residuals. Their difference, however, is shown to be negligible if the cross-sectional variance of the beta coefficients is not too volatile.

[46] Again, n=36 in *full sample* while n=26 in *restricted sample*.

(hereafter **IDIO**). The final form is:

$$(7) \qquad \frac{1}{n}\sum_i Var(R_{it}) = Var(R_{mt}) + \frac{1}{n}\sum_i Var(\varepsilon_{it})$$

$$VAR_t = MKT_t + IDIO_t$$

Appendix V

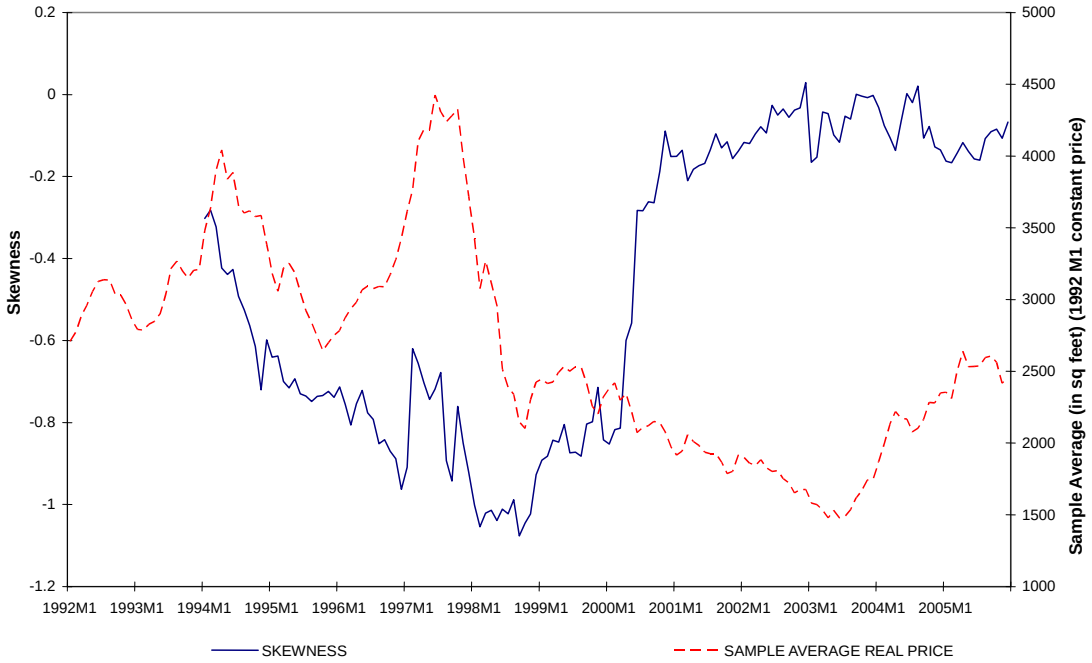
Further Results on the distribution of (sample) correlations

In the main text, we focus on the evolution of the mean of the correlation distribution. In fact, the evolution of the higher moments of the correlation distribution is also interesting. While the standard deviation is weakly negatively correlated to the average correlation (their correlation is -0.37),[47] the skewness of the distribution of correlations is like a mirror image of the mean correlation, with a correlation of *-0.95*! It further reinforces the idea that there may be a structural change in the distribution of correlation coefficients. The distribution of correlations is generally negatively skewed (or called skewed to the left). Numerically speaking, the skewness "increases" from about -0.3 to more than -1 a few months before 1999 M1. It then declines and becomes close to zero since 2001 (i.e. the distribution becomes approximately symmetric). The following graphs provide a visualization of these discussions.

Figure A2-1 Standard Deviation - Rolling Window Correlation Coefficients for Full Sample Price

[47] Details of all the correlations calculations are available upon request.

Figure A2-2 Skewness - Rolling Window Correlation Coefficients for Full Sample Price



In the text, we focused on the mean correlation of trading volume. Now we show the standard deviation and the skewness of trading volume correlation distributions. The standard deviation is (weakly) negatively correlated to the mean correlation among estates (with a correlation of -0.37), the skewness of trading volume correlations displays more dramatic movements. It starts with a value about -0.25, and reaches its numerical peak to about -1.8 in early 1999. In a few months, however, it sharply declines to about -0.5 and fluctuates since then. At the end of our sample, it almost restores to the value of -0.25, where the skewness series begins. And as in the case of price, the skewness of correlations among estates' trading volume is strongly related to the mean counterpart, with a correlation of -0.89! The following figures provide visualization.

Figure A2-3 Standard Deviation - Rolling Window Correlation Coefficients for Full Sample VOL

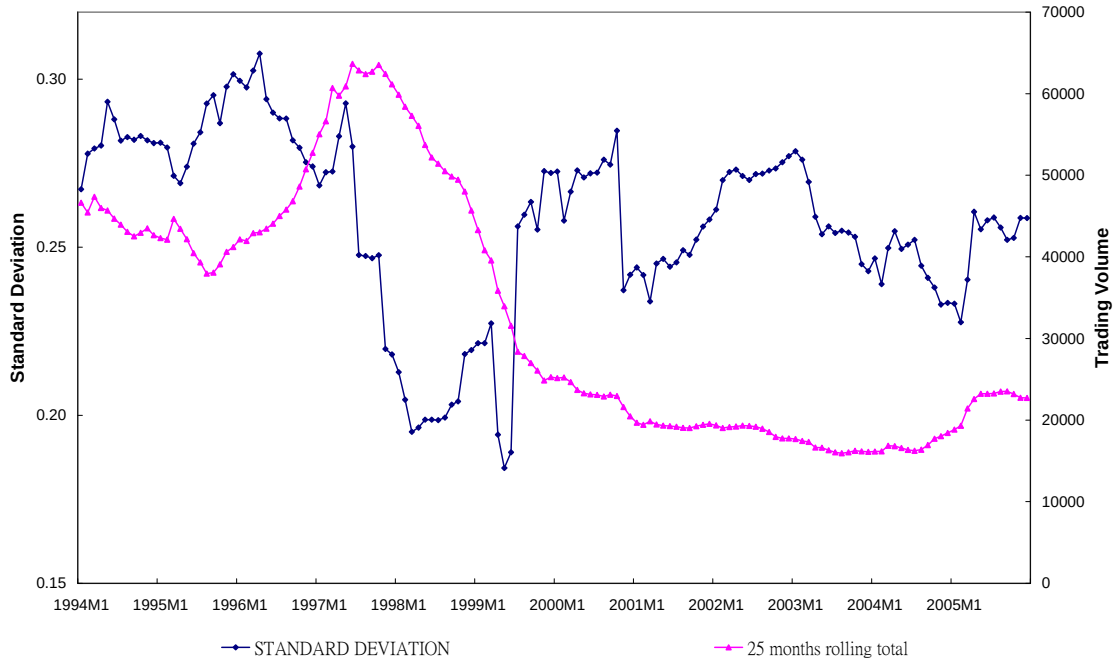
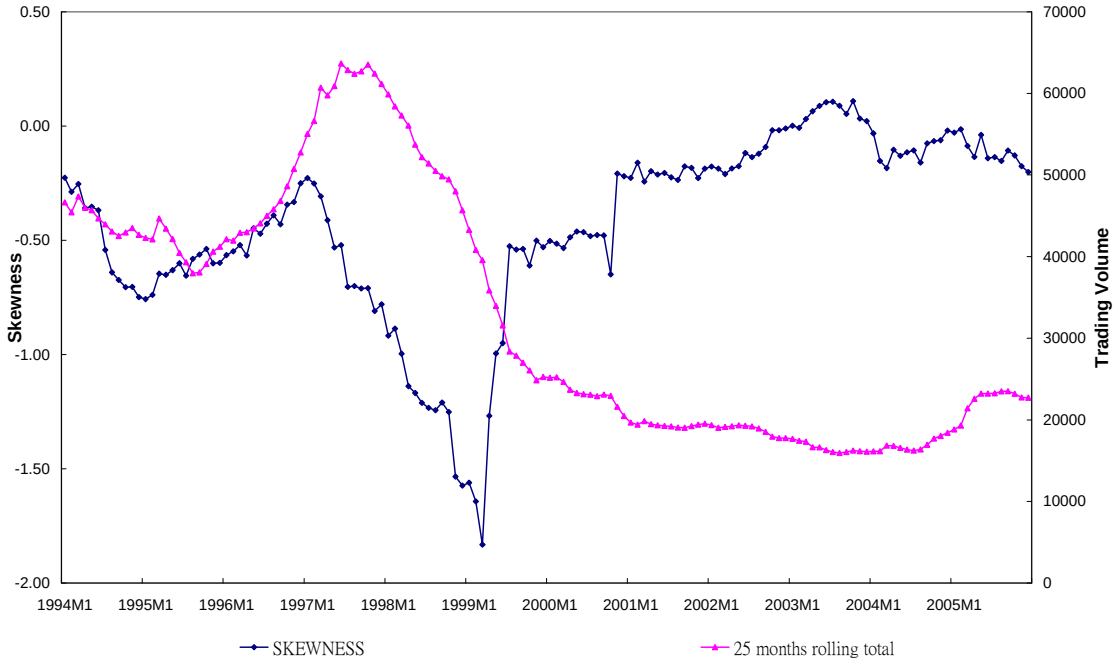


Figure A2-4 Skewness - Rolling Window Correlation Coefficients for Full Sample VOL



In the main text, we focus on how the ratio of IDIO to VAR is related to the mean correlation. Here we attempt to cast further light on the relationship between the higher moments of all pair wise correlation (i.e. standard deviation and skewness) and the ratio of IDIO to VAR. Standard deviation co-move with the ratio of IDIO to VAR until the end of 2000. On the other hand, the skewness measure of correlation coefficients moves closely with IDIO/VAR throughout the sample period. The correlation coefficient is 0.91. The increase in the skewness of the correlation distribution among different estate prices is associated with an increase in the share of idiosyncratic volatility in the total volatility. The following figures provide visualization.

Figure A2-5 Variance Ratio and Standard Deviation of Correlations - Full Sample

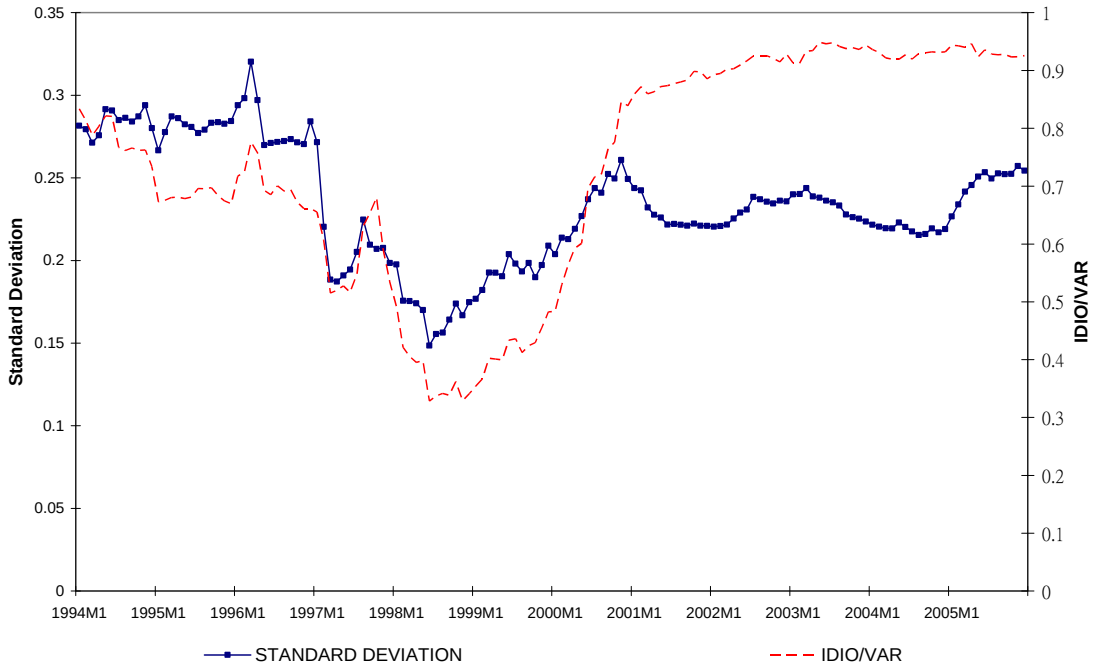
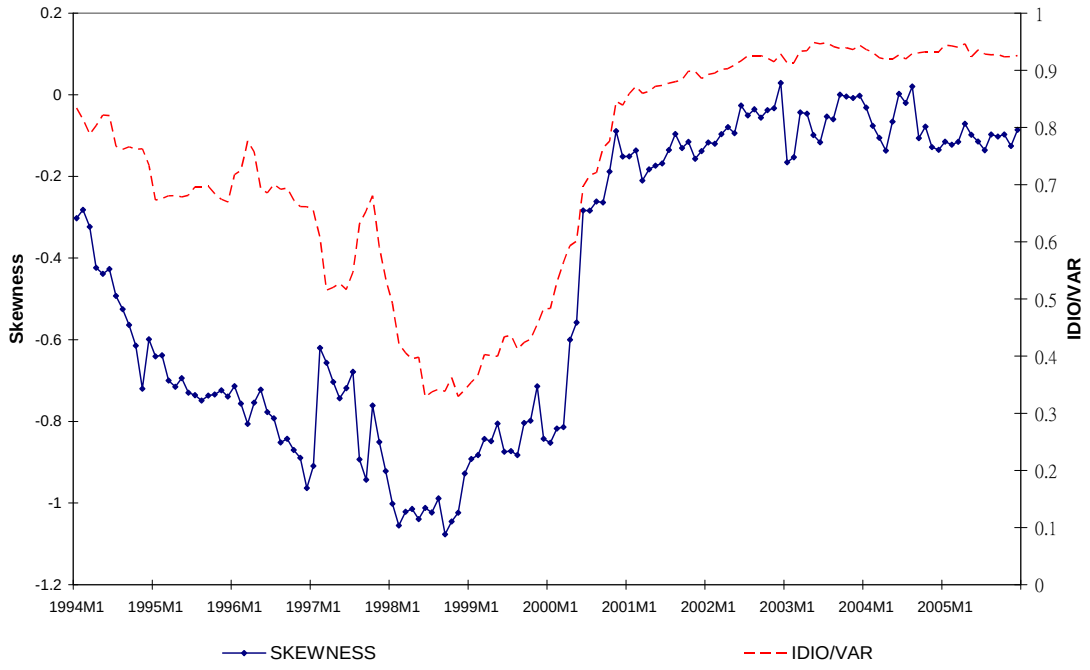


Figure A2-6 Variance Ratio and Skewness of Correlations - Full Sample



Appendix VI

Decomposition of the mean correlations

This section provides the details of the decomposition of the mean correlations. First, we fix a particular window. Assume that there are *n* different estates and there are totally *N* different correlations (with all the "own correlations" removed), then, by definition, the Mean of correlation

$= \sum_{i=1}^{n} \sum_{j=1, i \neq j}^{n} \rho_{i,j} / N$, where $\rho_{i,j}$ represents the correlation between estate *i* and *j*. Now let us focus on the sum of all correlations, $S \equiv \sum_{i=1}^{n} \sum_{j=1, i \neq j}^{n} \rho_{i,j}$, as *N* is simply a constant.

Notice that we can rewrite S as

$S \equiv \sum_{i=1}^{n} \sum_{j=1, i \neq j}^{n} \rho_{i,j} = \sum_{i \in G_1} \sum_{j \in G_1, i \neq j} \rho_{i,j} + (\sum_{i \in G_1} \sum_{j \in G_2} \rho_{i,j} + \sum_{i \in G_1} \sum_{j \in G_2} \rho_{j,i}) + \sum_{i \in G_2} \sum_{j \in G_2, i \neq j} \rho_{i,j}$, where $G_i, i = 1,2,$ represent different groups of estates, which are mutually exclusive.

Thus, the last expression simply means that we can express S as the sum of three quantities. The first term is the total correlations among estate pairs where both estates come from group 1, while the third is the total correlations among estate pairs where both estates come from group 2. The second term is the total correlations among estate pairs where one estate is from group 1 and the other is from group 2.

To give an example, let us assume that there are totally 6 estates A, B, C, D, E and F. Let us assume further that estate A, B and C belong to group 1 and estate D, E and F belong to group 2. In this case, we can write

$S = \sum_{i \in G_1} \sum_{j \in G_1, i \neq j} \rho_{i,j} + (\sum_{i \in G_1} \sum_{j \in G_2} \rho_{i,j} + \sum_{i \in G_1} \sum_{j \in G_2} \rho_{j,i}) + \sum_{i \in G_2} \sum_{j \in G_2, i \neq j} \rho_{i,j}$

$= 2*\{(\rho_{A,B} + \rho_{B,C} + \rho_{A,C}) + (\rho_{A,E} + \rho_{A,F} + \rho_{A,G} + \rho_{B,E} + \rho_{B,F} + \rho_{B,G} + \rho_{C,E} + \rho_{C,F} + \rho_{C,G})$

$+ (\rho_{E,F} + \rho_{E,G} + \rho_{F,G})\}$,

where the first bracket is the sum of all correlations among estate pairs where both estates come from group 1, the second bracket is the total correlations among estate pairs where one estate is from group 1 and the other is from group 2, and the third is the total correlations among estate pairs where both estates come from group 2. Notice that there is a factor "2" in both the first and the third term because $\rho_{A,B} = \rho_{B,A}, \rho_{B,C} = \rho_{C,B}, \ldots$ etc.

In general if there are n_1 estates in group 1, and n_2 estates in group 2, then there are totally $N_1 \equiv n_1(n_1 - 1)$ correlations in the first term, $N_2 \equiv n_2(n_2 - 1)$ correlations in the third term, $N_{12} \equiv n_1 \bullet n_2$ correlations in the second term. Thus, the term

$S_1 \equiv \sum_{i \in G_1} \sum_{j \in G_1, i \neq j} \rho_{i,j} / N_1$ measures the mean correlation among the estates within group 1, the term $S_2 \equiv \sum_{i \in G_2} \sum_{j \in G_2, i \neq j} \rho_{i,j} / N_2$ measures the mean correlation among the estates within group 2, and the term $S_{12} \equiv \sum_{i \in G_1} \sum_{j \in G_2} \rho_{i,j} / N_{12}$ measures the mean correlation among estate pairs where one estate is from group1 and the other is from group 2.

Now assume that we calculate S_1, S_2, S_{12} for each window. As we roll over different windows, we can trace the changes of the mean correlations within group as well as among groups.