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

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This study of the co-movements of transaction prices and trading volumes reveals that the mean correlation of prices and trading volumes alike, among different housing sub-markets, increase during the market boom. After a financial crisis, the correlations dramatically drop 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 with a family of theories that emphasize on the "regime switch" in expectations.

Keywords:

Financial Crisis; Hedonic Pricing; Structural Break; Evolution of Valuation; Rolling Regression

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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 a financial crisis. Yet the continuous participation of a significant share of the population remains a mystery to be solved. As the quotations from Homer Hoyt and George Soros suggest, people may indeed be aware of the apparently "irrational component" of asset pricing during a "boom", yet participate anyway. After a "crash" or a "crisis" in the asset market, however, 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, composition of assets that 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 with 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 previous efforts typically focus on whether the real estate market causes a financial crisis, or the impact of a financial crisis on the real estate market, this paper instead 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 a real estate developer and specific location characteristics tend to change relatively slow. This is especially true for residential housing as school districts and other "local public goods" are proven to be important empirical determinants for housing prices.[3] The previous literature seems to focus on the 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 has experienced a dramatic crisis and the co-movements among different submarkets potentially change. Since these factors do not proportionally change in a crisis, any changes that we can measure can be

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[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.
[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.

attributed to other factors, such as the wealth effect on housing demand, or some expectation factors.

This project may also shed light on the discussion about the correlation between house price and trading volume. Existing dynamic general equilibrium models of housing prices, such as those by Kan et al. (2004), Ortalo-Magne and Rady (2006), and Leung et al. (2007), etc., have shown that the co-movements among property price and trading volume at the national or city level are related to the movement of economic fundamentals (such as GDP), collateral constraints, among other factors. However, studies on correlations among house prices of different sub-markets, or correlations among the trading volumes of different sub-markets, are under-explored. In particular, if the price and trading volume correlations at the sub-market level (i.e. within a city) are merely driven by aggregate shock or financial constraints, we would expect that those correlations among the sub-markets would be roughly constant over time. If such 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 searching and bargaining in a decentralized housing market. Moreover, even if the situation is complicated by the fact the banks may have loan preference on some sub-markets over 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 take time as well. Thus, by simply inspecting the time-pattern of price and volume correlations among estates, this will shed light on the related literature.

There is 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 (2007) propose a model in which agents use over-simplifying models for forecasting. Over time, the discrepancy between model prediction and reality reaches a certain threshold and investors will switch to another forecasting model, which results in a “paradigm shift” in investment behavior. While these research work 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, this may lead to a change in the correlations among housing prices, as in Wang et al (2000). Our empirical studies can formally examine this possibility.

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 such literature may be instructive. Contagion can be defined in many ways and the methodology of the empirical analysis is often accordingly chosen (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 instances of empirical work on contagion focus on the change in the correlation in returns after a shock.

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 all agents switch from one model to another, dramatic changes in the asset price process can happen.

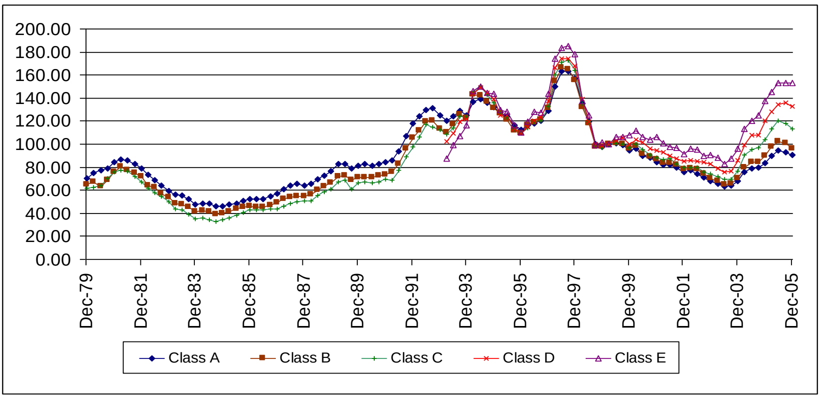
In the context of Hong Kong, it is instructive to consider real estate development (or simply *estate)* as a submarket.[4] The merits of this approach are clear. Cities and nations may differ in many different aspects which can account for their housing markets to react differently after a crisis. On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

[4] An “estate” in Hong Kong is similar to a “housing development” in the United States. In Hong Kong, an estate is usually constituted of 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. The size of some of the estates can make them form a distinct community.

very difficult to "extend" or "alter" the physical structure, which facilitates a 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 allows us to focus on the *change of co-movements* before and after the financial crisis.

It is instructive to start with a 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 differences in attributes into consideration.[6] Dramatic movements in nominal housing prices are observed in this period. The indices begin with values slightly above *60* 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 Quarterly Housing Price Indices (Official Data; in Real Terms) (1999 Q1=100)



[5] In contrast, some detached houses in the United States would allow for significant extensions, including the adding of a basement, or building a small house in 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 the price indices are constructed, and whether those methods have changed over time.

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 coefficients over time, and the ability to apply 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 "moving window."[7] This enables us to detect changes in the correlation estimates which are affected by abnormal events, or the "financial crisis shocks" that we attempt to identify, given the limiting sample size. It also differentiates our paper from some earlier efforts that adopt a "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 coefficients 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 the 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 a 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

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

[8] Some authors have reservations about 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 unsuitable in the contagion literature as a 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.

major estates in Hong Kong, which is a balance panel dataset.[9] Our *full sample* contains more than 222,000 transactions in a period of 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 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 that have 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, standard deviation and 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), which suggests 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 does not rely on any "bubble test", which can be controversial.[13]

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[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 new developments into the sample will create an unbalanced panel and that is left for future research.
[10] In Hong Kong, most housing transactions can be finished in a month. See Leung, Leong and Chan (2002).
[11] The results of the *restricted sample* are 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).

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] stable exchange rate, 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 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, and high-rise buildings, which are almost impossible to be extended, rather than detached houses. All these contribute to minimizing the cross-sectional as well as time aggregation bias.[17]

Figure 1b plots the 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 gave rise to arguments before the change of sovereignty in 1996, Asian Financial Crisis in 1997/98, global technology (dot-com) stock meltdown in 2000, and outbreak of the 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) whether the correlation structure of housing price among residential estates displays an asymmetric pattern over the cycle, and (2) whether the correlation structure of trading volume demonstrates a similar pattern as the real housing return.[18]

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[14] Among others, see Acemoglu and Robinson (2006) for a discussion on why institutions are important.

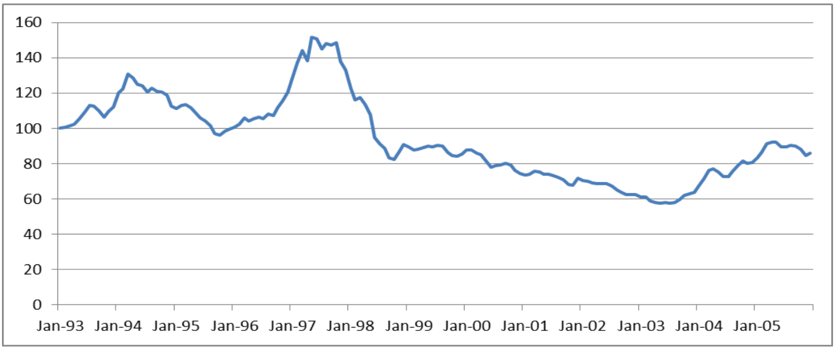
[15] Due to the many agreements between the British and the Chinese governments, the boundary of Hong Kong is legally fixed and cannot expand, even after the turnover to the Chinese government. This is in sharp contrast to cities such as the larger L.A. or Houston, where geographical expansion is feasible.

[16] The exchange rate between the Hong Kong and U.S. dollars has not changed since the mid-1980s.

[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 investigation approach. The results are available upon request.

Figure 1b Time Plots of Real Housing Price (Calculations by Authors) (Jan 1993 =100)



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 that we will 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 Registry Department of the Hong Kong government and reorganized them into a 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 thirty-six large private residential estates (or sometimes called "complexes"), which are on the "*most frequently traded list*" of the EPRC dataset. The 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. In total, there are almost 162,000 housing units, which is roughly 15% of all the private sector housing in 1992. [19] The respective final completion dates, number of housing units, and 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

[19] According to official data, the total stock of private housing units was about 1.087 million at 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.

the trading volume series are non-stationary over time, the present study will "detrend" the variables by taking the first difference. This avoids the problem of spurious correlation.

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

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 from the Agreement for Sales and Purchase (ASP) contract is employed.[21] As Tables 2b and 2c show, the selected estates cover a wide range of prices, before or after adjustment for inflation, which will enable us to track the heterogeneous responses to a shock among different estates.

Since this paper studies how the correlations among the prices of different estates change over time, the measurement of the price deserves some serious attention. It is well known that a major obstacle to accurately measuring housing price 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 heterogeneity, this study follows the literature and adopts a 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 allow 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:

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

where *lnP* 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 vectors of

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[21] In Hong Kong, as in many other places, several agreements need to be signed during the "transaction process". The other contracts, such as the 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.

[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 effects.

[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.

coefficients obtained in each period t. We construct a constant-quality price index for each estate.[26] Moreover, 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.

Table 2b Summary Statistics for the Monthly Nominal Housing Price (Per Square Feet Price in Current HK Dollars)

Estate Name	Maximum	Minimum	Mean	Standard deviation
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

[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.

Table 2c Summary Statistics for the Monthly Real Housing Price (Per Square Feet Price in 1992 M1 Constant HK Dollars)

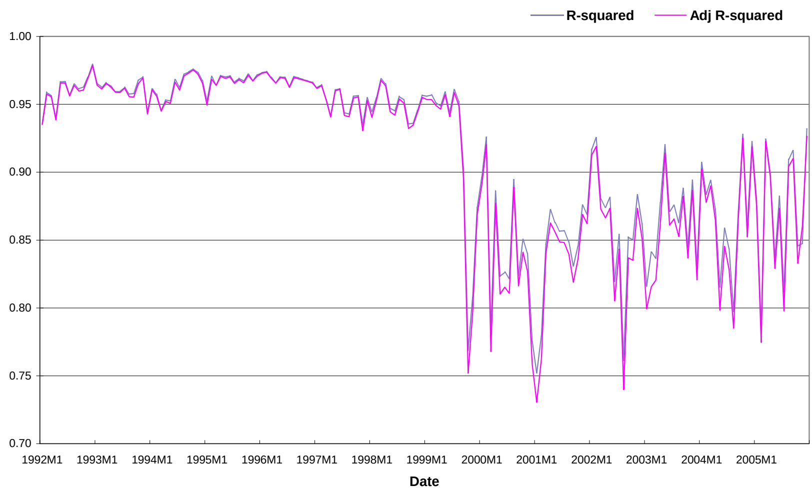
Estate Name	Maximum	Minimum	Mean	Standard deviation
Allway Garden	2961.6	896.5	1728.3	513.7
Amoy Garden	3836.5	1223.9	2330.4	646.4
Belvedere Garden	3791.9	884.5	2275.6	677.9
Beverly Hill	6994.8	944.6	4330.4	1006.0
Chi Fu Fa Yuen	4253.0	1429.2	2685.5	695.3
City Garden	5549.4	1644.6	3425.2	924.9
City One 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 Summary Statistics for the Monthly Real Rates of Return (in Percentage)

Estate 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

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 coincide each other, which suggests that there are 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 R^2 and adjusted R^2) of this model in the later part of the sampling period (after mid-1999). We employ the structural break test developed by Andrews and Ploberger (1994) and confirm that both R^2 and adjusted R^2 experience *a break in August 1999*.[27] Also, the values of the R^2 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 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*. This may reflect a "structural change" in the housing market, such as a change in the market expectation.

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



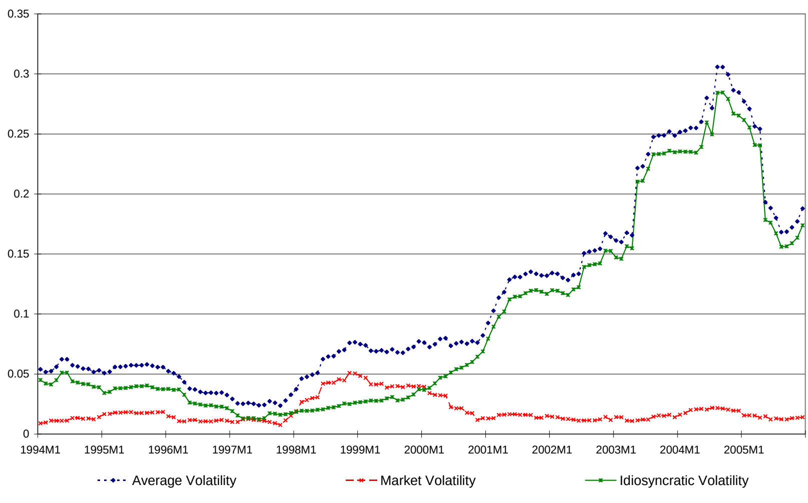
To further investigate the possibility of a "structural change" in the housing market, we follow the volatility decomposition procedure developed by Campbell, Lettau, Malkiel, and Xu (2001) (hereafter CLMX).[28] In the context of the stock market, CLMX attempt to decompose the volatility of individual stocks into "market volatility" and "idiosyncratic volatility." In a sense, this method is "model free." It does not require the researchers to estimate either

[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 for studying the correlation between detrended trading volumes.

the betas (covariances) for individual assets, or highly parameterized time-varying volatility models. Details of the CLMX "model-free" return decomposition can be found in the Appendix.

In Figure 2b, we plot the time series of a 24-month rolling window aggregate market variance (MKT), average estate-level variance (IDIO), and total variance (VAR) by giving equal weight to 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, which contributes about ***73%*** of the total variance for the whole sample period. This is especially true in later years. While the share of the idiosyncratic component only accounts for 60% of the total variation before 2001, the same ratio jumps to about ***92%*** in the post 2001 period! As in CLMX, a higher average idiosyncratic risk together with an 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 move closely together. While it is premature to reach a conclusion with only Figures 2a and 2b, they 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 detail in the following sections.

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



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 is being selected. Thus, these correlation coefficients are regarded as random variables.[29] They are computed for each possible combination of pairs 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" need *not* be normal, or conform 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 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, and (4) significantly negative for each window that we estimate. The precise mathematical formulas are given in the Appendix.[30]

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). This is followed by more diagnosis of the results.

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[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 that those estates may be "substitutes" in that particular period of time. The details are available upon request.

4.1 Overview for the Trading Volume and Quality-Controlled Returns

Since 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 rates of return for the 36 estates. In general, the standard deviation of the real rates of return is high, reflecting considerable investment risk in the housing market. Tables 3a and 3b have provided 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, essentially produces the same results. In other words, the dynamics of the 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.

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 statistically significant and insignificant ones) is very large and not less than 64% throughout, which indicate that 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. This 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 testing, 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*" of 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. uncorrelated).

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[31] The result is available upon request.

Table 3a Summary Statistics for the Monthly Trading Volume

Estate Name	Mean	Standard deviation	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

Notes: * denotes maximum, **denotes minimum.

Table 3b Summary Statistics for the Detrended Monthly Trading Volume

Estate Name	Mean	Standard deviation	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

Notes: * denotes maximum, **denotes minimum.

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

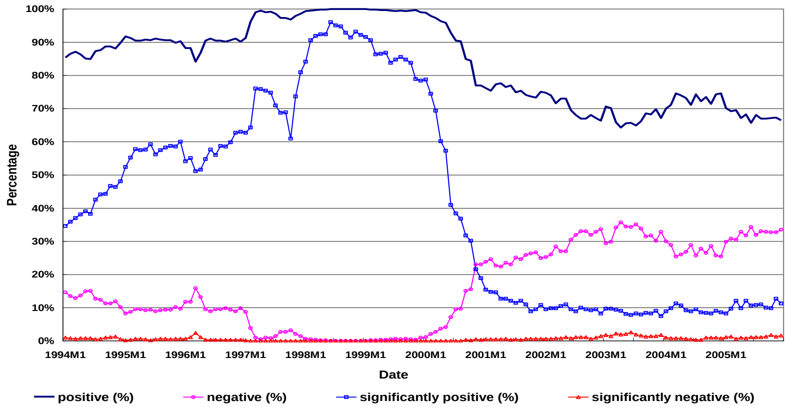
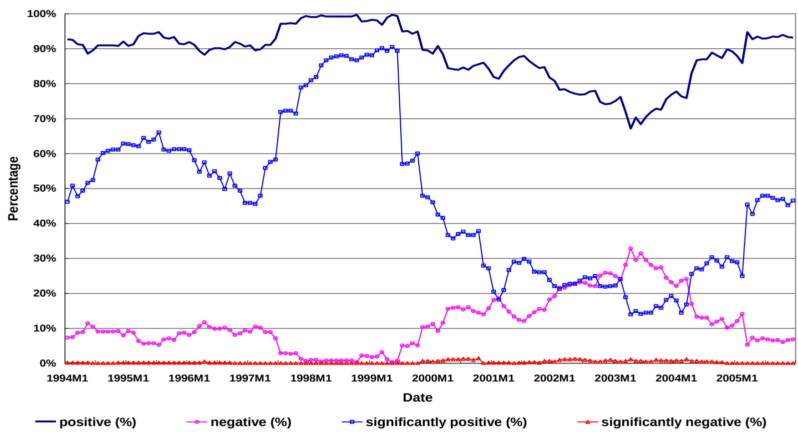


Figure 3b shows the same kind of time plots for detrended trading volume in the *full sample*. As the case of detrended prices, the share of positive correlations is in general very large and not fewer than 67% throughout. As well, like the case of prices, the share of significantly positive correlations seems to exhibit some kind of "structural change" after the Asian Financial Crisis. It dramatically increases, and somehow persistently until mid-1999. The share of 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.

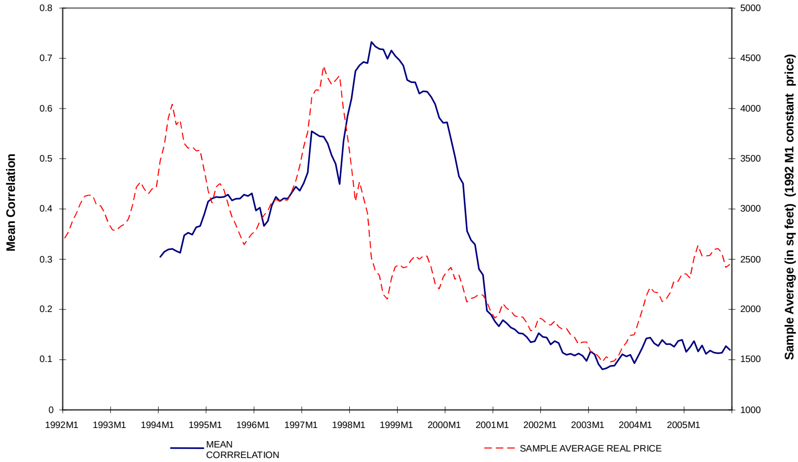
Figure 3b Count of Correlation Coefficients in Each Window for Full Sample VOL



4.2.2 The Summary Statistics of Correlation Coefficients

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 a total of 6 different pair-wise correlations. Furthermore, for the sake of argument, let us say that 4 of them are 0.5 and the other two of them are -0.9. Clearly, the share of 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 correlations, 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). As well, for comparison, we also provide the time plot of the value-weighted average of the sample price (dotted red line).

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



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 China's central government and led to the recovery of the Hong Kong economy,

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[32] It is not surprising that there are structural breaks in these series. Results are available upon request.

including the housing market. This 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 and vector error correction model (VECM), which are more suitable for trend-stationary or first-difference-stationary type processes. The application of 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 pose a challenge to theories which attempt to explain housing price dynamics by aggregate shocks alone. By the same token, the continual process of sub-urbanization and improvement of transportation networks *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 volumes.

Interestingly, the distribution of trading volumes displays a similar pattern as the prices. Figure 5 shows the mean of the (detrended) trading volume in the *full sample* (solid blue line). For comparison, the rolling total of the trading volume in the 25-month sample 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 loses almost all the "growth" accumulated in 5 years! It then fluctuates and goes down to almost 0.1. In the later months, the mean correlation of the trading volume is restored 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. Furthermore, as in the case of price,

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[33] In fact, we can statistically confirm that a structural break occurs in this series as well. The details are available upon request.
[34] Instead of plotting the series of monthly trading volumes which is quite erratic throughout the sample period, we plot the rolling total of the trading volume in a 25-month sample. The rolling total of the 25-months is selected to keep the consistency of information set that is used to compute rolling correlations of detrended volume.
[35] Not surprisingly, we can find statistical evidence of a structural break in this time series.

the skewness of correlations among the trading volume of the estates is strongly related to the mean counterpart, with a correlation of -0.89!

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

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

In summary, it seems that both in price and 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. Moreover, while the mean correlations (for both price and trading volume) increase, the skewness measures of the correlation distribution become significantly more negative. As the mean correlations collapse, so do the skewness measures.

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

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 these distributions of correlations, this section selects two polar cases and examines in greater detail, how their corresponding distributions differ. Figures 6a and 6b show the frequency distributions of all pair wise correlations for the *full sample* price (ROR) and volume (VOL) in two selected windows. They are the windows with the highest average correlation in price (the 2 year period ends with 1998 M6) and that with the lowest average correlation (the 2 year 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 Distributions of Correlation Coefficients during the Most Correlated and the Least Correlated Periods - Full Sample Price (ROR)

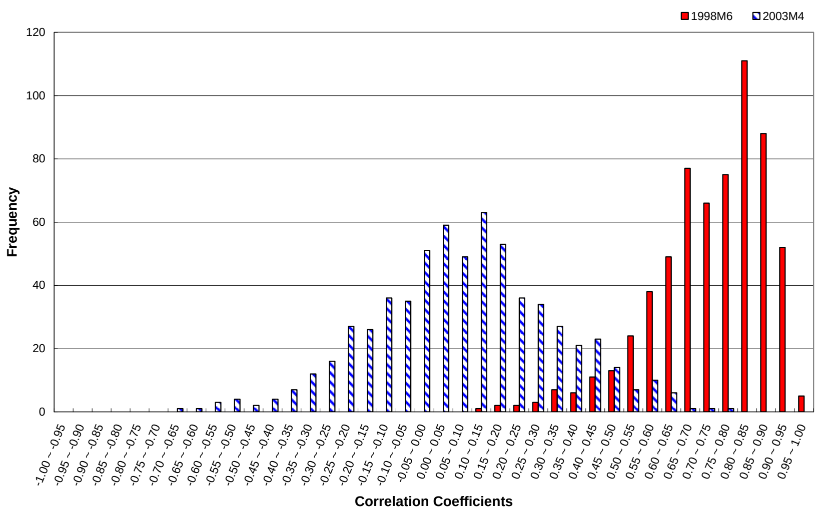
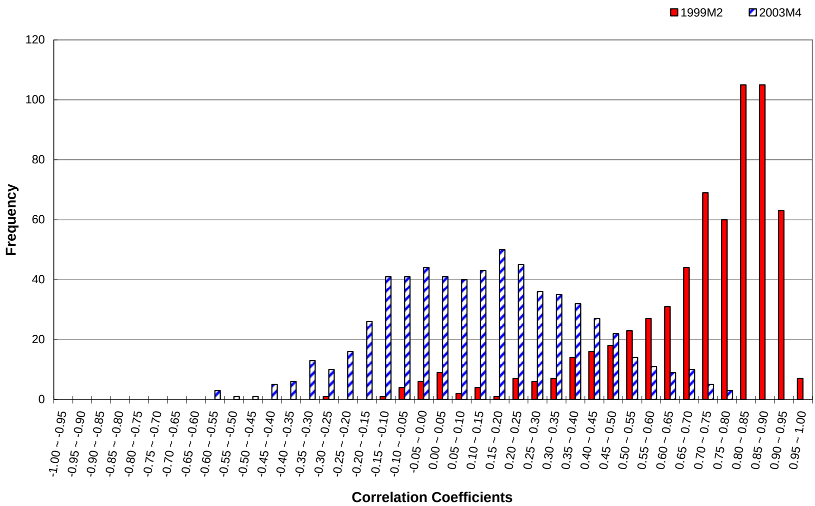


Figure 6b Distributions of Correlation Coefficients during the Most Correlated and the Least Correlated Periods - Full Sample VOL



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 be a market-wide factor which drives up the property prices in different estates in the same direction. Later, the Asian Financial Crisis began in Thailand on 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 lifted up the interest rate, which resulted in a sharp slump in the equity markets. At the same time, the "85,000 policy" was announced by the former Chief Executive, Chee Hwa Tung, in his first Policy Address on October 8, 1997. He promised to provide affordable housing for the general public and 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 asset values[37], and the housing prices in different estates declined 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 a positive one, the distribution becomes more negatively skewed.

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[37] Ironically, after the housing price collapses, 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).

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 the correlation coefficients shows a lower average value, a larger standard deviation and an approximately symmetric shape, which mean that some of the estate pairs are highly positively correlated while some, are negatively correlated. There are a number of potential reasons for why the estates responded differently to the shock during the outbreak of SARS. First, SARS only had a weak influence on the market-wide factor of property price determination. Estate-specific characteristics may still be the dominant factor. Second, while SARS brings a general downturn in the economy, the spread of the virus seemed to be geographically concentrated.[39] Third, there was a sudden drop in transaction volume during April 2003 and the price measure might have been "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 structure of the 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

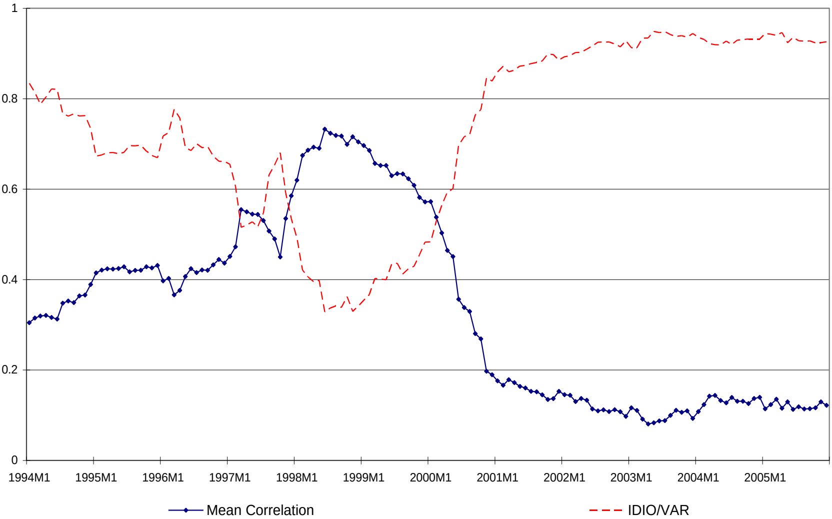
This subsection attempts to connect the moments of the correlation distributions calculated in an earlier section to the volatility decomposition developed by Campbell et al. (2001), and applied to the Hong Kong market (results presented in Section 2). Figure 7 displays the relationship between correlation 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 about -0.99 between the two series! This confirms similar findings in the previous

[39] For instance, out of 1755 cases in Hong Kong, Amoy Garden alone accounts for 321 of them (about 18%). Medical staff account for another 386 cases (about 21%). In order to prevent the spread of viral pneumonia, all residents in Block E of 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.

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

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 returns, but it is not clear how this method is applied 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 basically capture the same phenomenon, and can be applied to both returns and trading volume. Perhaps future research can further explore this issue.

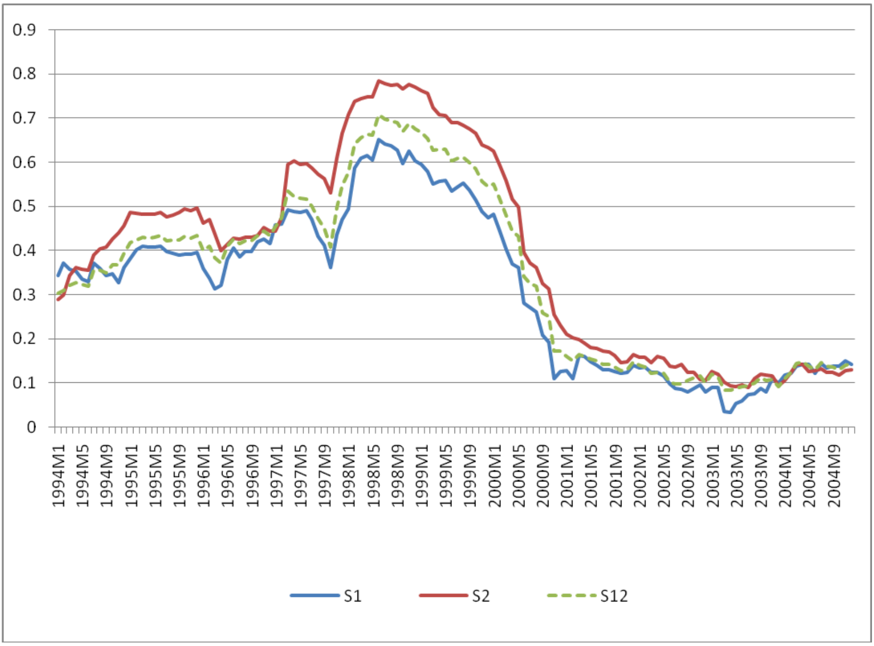
Figure 7 Variance Ratio and Mean Correlation - Full Sample



5.2 Can the Results be Explained by Composition Change?

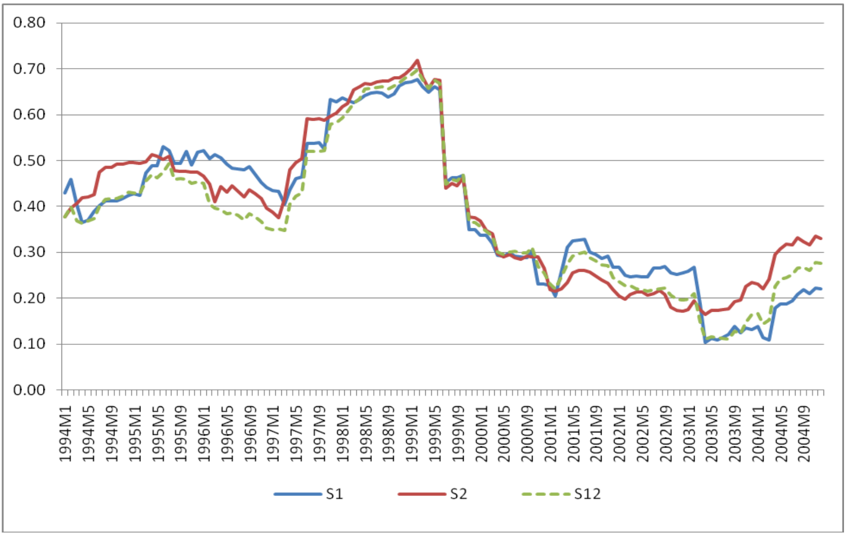
In the previous sections, we have adopted a "non-discriminating approach" in the computation of the mean correlations on housing returns and trading volume, meaning that we simply pool all 36 estates together in our calculation. It is possible, however, that those 36 estates actually come from different distributions. For instance, some of them may be "luxurious housing" while some are "normal housing." It is possible that correlations within the same "class" do not change during a financial crisis, and yet the correlations among estates from different classes significantly change. 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" consisting of all estates on the Hong Kong Island, plus Parc Oasis and Village Gardens, and the "normal group" including the rest of the estates. We find that whether we use the average total sale price as the criteria, or based on previous research on the Hong Kong housing market, or some subjective assessments in the media, we will obtain the same classification.[41] In the Appendix, we show in detail how the mean correlation can be interpreted as a weighted average of three sub-group mean correlations, which are S1 (mean correlation within the luxurious group), S2 (mean correlation within the normal group), and S12 (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 Figures 8a and 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, there is a "universal change" in the mean correlation among estates*, whether within or between groups, and whether it is in terms of the returns or trading volume.

Figure 8a Decomposition of the Mean Correlation of Returns among Different Estates



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

Figure 8b Decomposition of the Mean Correlation of Trading Volumes among Different Estates



5.3 A Simple Story for the Empirical Findings

The previous subsections have examined in great detail, the robustness of the empirical results. To close this section, this subsection attempts to give a simple story that can account for all of these "stylized facts." During the first sub-period (before 1997), everyone had good expectations 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 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 started 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) report in a survey of people who started new businesses, they were asked both the chances 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 "(l)otteries 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 around when they see that the price "collapses."

Notice that this explanation differs from the finance literature in at least one important dimension. Among others, Ang and Chen (2002), Connolly and Wang (2003), and Longin and Solnik (2001), find that correlations among financial markets increase during market *downturns* rather than upturns. Recent theoretical work, such as Veldkamp (2006) and 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 uses 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 of 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 rates of return among the most frequently traded estates, and find that the co-movements among different sub-markets significantly vary.

While our paper is empirical, it sheds light on several theoretical instances of literature. First, we find that in sharp contrast to the finance literature, 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 occurred 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 SARS. The situation of the 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! Moreover, 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 financial assets and more theoretical work is needed. Furthermore, the pattern of the price and volume correlations among different sub-markets identified in this paper may not be easily explained by the family of theories which merely emphasize aggregate shock, aggregate financial constraints or search frictions. It should be emphasized that existing theories have made important contributions to our understanding of real estate markets in "normal times." On the other hand, the "new stylized facts" in this paper focus on the ability for those models to account for markets in “crisis times”. Obviously, future research efforts should be invested on building a “*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 the bounded rationality of agents. For instance, in Hong, Stein and Yu (2007), agents use an 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 by Peng and Xiong (2006), among others, also helps 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 the 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 and the housing markets) are influenced by the U.S. financial market variables and significant regime switching have been observed. Future work should try to relate the evidence at the micro- and the aggregate-levels 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 the confidence interval is based on some assumptions of the underlying distribution. If the market, as a system, really experiences a structural change,

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

then what is the appropriate distribution? Previous work on structural breaks tend to limit their attention to uni-variate cases and the structural change of variables to a very specific form, and test whether such form of breaks happens. Now it is the 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 future research.

Future research can also be extended in other directions. First, the sample can be enlarged. This paper 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 less frequently traded estates, or even other cities for comparison. Second, this research only focuses on residential housing. Future research efforts should extend to commercial real estate. Perhaps more importantly, a unifying framework should be built to test both the case of financial assets (in which price correlation will decrease with price) and the case of real estate studied here (in which price correlation will increase with price).

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References

Acemoglu, D. and Robinson, J. (2006). *Economic Origins of Dictatorship and Democracy*. Cambridge: Cambridge University Press.

Andrews, D. and Ploberger, W. (1994). Optimal Tests When a Nuisance Parameter is Present Only under the Alternative, *Econometrica*, **62,** 6, 1383-1414.

Ang, A. and Chen, J. (2002). Asymmetric Correlations of Equity Portfolios, *Journal of Financial Economics*, **63,** 3, 443-494.

Audrino, F. and Barone-Adesi, G. (2003). Semiparametric Multivariate GARCH Models for Volatility Asymmetries and Dynamic Correlations, *Working Paper*, University of Southern Switzerland.

Berg, L. (2005). Price Indexes for Multi-Dwelling Properties in Sweden, J*ournal of Real Estate Research*, **27,** 1, 47-82.

Box, G.E.P. (1949). A General Distribution Theory for a Class of Likelihood Criteria, *Biometrika,* **36,** 3-4, 317-346.

Campbell, J.Y., Lettau, M., Malkiel, B.G. and Xu, Y. (2001). Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk, *Journal of Finance,* **56,** 1, 1-43.

Cappiello, L., Engle, R. and Sheppard, K. (2003). Asymmetric Dynamics in the Correlations of Global Equity and Bond Returns, *ECB Working Paper No. 204*.

Case, B. and Quigley, J.M. (1991). The Dynamics of Real Estate Prices, *Review of Economics and Statistics*, 7**3,** 1, 50-58.

Chakrabarti, R. and Roll, R. (2002). East Asia and Europe during the 1997 Asian Collapse: A Clinical Study of a Financial Crisis, *Journal of Financial Markets,* **5,** 1, 1-30.

Chang, K.L., Chen, N.K. and Leung, C.K.Y. (2011). In the Shadow of the United States: The International Transmission Effect of Asset Returns, City University of Hong Kong, mimeo.

Christano, L. and Eichenbaum, M. (1987). Temporal Aggregation and Structural Inference in Macroeconomics, *Carnegie-Rochester Conference Series on Public Policy,* **26,** 63-130.

Christano, L., Eichenbaum, M. and Marshall, D. (1991). The Permanent Income Hypothesis Revisited, *Econometrica*, **59,** 2, 397-424.

Connolly, R. and Wang, A. (2003). International Equity Market Comovements: Economic Fundamentals or Contagion, *Pacific-Basin Finance Journal*, **11,** 1, 23-43.

Drobetz, W., and Zimmermann, H. (2000). Volatility and Stock Market Correlation, *Working paper*, University of St. Gallen.

Dungey, M., Fry, R., González-Hermosillo, B. and Martin, V.L. (2005). Empirical Modelling of Contagion: A Review of Methodologies, *Quantitative Finance*, **5,** 1, 9-24.

Dungey, M. and Zhumabekova, D. (2001). Testing for Contagion Using Correlations: Some Words of Caution, *Pacific Basin Working Paper Series No. PB01-09*, Federal Reserve Bank of San Francisco.

Engle, R.F. (2002). Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models, *Journal of Business and Economic Statistics*, **20,** 3, 339-350.

Englund, P., Quigley, J. and Redfearn, C. (1999). The Choice of Methodology for Computing Housing Price Indexes: Comparisons of Temporal Aggregation and Sample Definition, *Journal of Real Estate Finance and Economics*, **19,** 2, 91-112.

Erb, C.B., Harvey, C.R. and Viskanta, T.E. (1994). Forecasting International Equity Correlations, *Financial Analysts Journal*, **50,** 6, 32–45.

Forbes, K. and Rigobon, R. (2002). No Contagion, Only Interdependence: Measuring Stock Market Co-movements, *Journal of Finance*, **57,** 5, 2223-2261.

Foster, D.P. and Nelson, D.B. (1996). Continuous Record Asymptotics for Rolling Sample Variance Estimators, *Econometrica*, **64,** 1, 139-174.
Gurkaynak, R. (2008). Econometric Tests of Asset Price Bubbles: Taking Stock, *Journal of Economic Surveys*, **22,** 1, 166–186.

Hanushek, E., Rivkin, S. and Taylor, L. (1996). Aggregation and the Estimated Effects of School Resources, *Review of Economics and Statistics*, **78,** 4, 611-627.

Hanushek, E., and Welch, F. (ed.) (2006). *Handbook of the Economics of Education*, Volume 1, 2, Elsevier.

Hirshleifer, D. and Teoh, S.H. (2003). Herd Behavior and Cascading in Capital Markets: A Review and Synthesis, *European Financial Management*, **9,** 1, 25-66.

Hong, H., Kubik, J. and Stein, J. (2004). Social Interaction and Stock-Market Participation, *Journal of Finance*, **59,** 1, 137-163.

Hong, H., Stein, J. and Yu, J. (2007). Simple Forecasts and Paradigm Shift, *Journal of Finance*, **62,** 3, 1207-1242.

Jennrich, R. I. (1970). An Asymptotic Chi-Square Test for the Equality of Two Correlation Matrices, *Journal of the American Statistical Association*, **65,** 330, 904-912.

Kan, K., Kwong, S.K.S. and Leung, C.K.Y. (2004). The Dynamics and Volatility of Commercial and Residential Property Prices: Theory and Evidence, *Journal of Regional Science,* **44,** 1, 95-123.

Kearney, C. and Potì, V. (2004). Idiosyncratic Risk, Market Risk and Correlation Dynamics in European Equity Markets, *The Institute for International Integration Studies Discussion Paper Series 15*.

Kearney, C. and Potì, V. (2006). Have European Stocks Become More Volatile? An Empirical Investigation of Idiosyncratic and Market Risk in the Euro Area, *The Institute for International Integration Studies Discussion Paper Series 132*.

Kwan**,** Y.K., Lui, F.T. and Cheng, L.K. (2001). Credibility of Hong Kong's Currency Board: The Role of Institutional Arrangements, in *Regional and Global Capital Flows: Macroeconomic Causes and Consequences*, eds. by T. Ito and A. Krueger, Chicago and London: University of Chicago Press, 233-259.

Lau, S.K. ed. (2002). *The First Tung Chee-Hwa Administration*. Hong Kong: Chinese University Press.

Leung, C.K.Y. (2004). Macroeconomics and Housing: A Review of the Literature, *Journal of Housing Economics*, **13,** 4, 249-267.

Leung, C.K.Y., Lau, G.C.K. and Leong, Y.C.F. (2002). Testing Alternative Theories of the Property Price-Trading Volume Correlation, *Journal of Real Estate Research*, **23,** 3, 253-263.

Leung, C.K.Y., Leong, Y.C.F., Chan, I.Y.S. (2002). TOM: Why Isn’t Price Enough?, *International Real Estate Review*, **5,** 1, 91-115.

Leung, C.K.Y. and Tang, E.C.H. (2011). Comparing Two Financial Crises: The Case of Hong Kong Real Estate Markets, forthcoming in *Global Housing Markets: Crises, Institutions and Policies*, eds. by A. Bardhan, R. Edelstein and C. Kroll, New York: John Wiley & Sons.

Leung, C.K.Y., Wong, S.K. and Cheung, P.W.Y. (2007). On the Stability of the Implicit Prices of Housing Attributes: A Dynamic Theory and Some Evidence, *International Real Estate Review,* **10,** 2, 65-91.

Leung, C.K.Y. and Zhang, J. (2011). "Fire Sales" in Housing Market: Is the House-Search Process Similar to a Theme Park Visit?, forthcoming in *International Real Estate Review*.

Longin, F. and Solnik, B. (2001). Extreme Correlation of International Equity Markets, *Journal of Finance*, **56,** 2, 649-676.

Lui, F.T., Cheng, L.K. and Kwan, Y.K. (2003). Currency Board, Asian Financial Crisis, and the Case for Put Options, in *Exchange Rate Regimes and Macroeconomic Stability*, eds. by L.S. Ho and C.W. Yuen, Boston, Dordrecht and London: Kluwer Academic Publishers, 185-214.

Malpezzi, S. (2002). Hedonic Pricing Models: A Selective and Applied Review, in *Housing Economics and Public Policy: Essays in Honor of Duncan Maclennan*, eds. by T. O'Sullivan, K. Gibb, Oxford: Blackwell, 67-89.

Ortalo-Magne, F. and Rady, S. (2006). Housing Market Dynamics: On the Contribution of Income Shocks and Credit Constraints, *Review of Economic Studies*, **73,** 2, 459-485.

Peng, L. and Xiong, W. (2006). Investor Attention, Overconfidence and Category Learning, *Journal of Financial Economics*, **80,** 3, 563-602.

Pericoli, M. and Sbracia, M. (2003). A Primer of Financial Contagion, *Journal of Economic Surveys*, **17,** 4, 571-608.

Quigley, J.M. (1995). A Simple Hybrid Model for Estimating Real Estate Price Indexes, *Journal of Housing Economics*, **4,** 1, 1-12.

Quigley, J.M. (1999). Real Estate Prices and Economic Cycles, *International Real Estate Review*, **2,** 1, 1-20.

Quigley, J.M. (2001). Real Estate and the Asian Crisis, *Journal of Housing Economics*, **10,** 2, 129-161.

Rigobon, R. (2003). Identification Through Heteroskedasticity, *Review of Economics and Statistics*, **85,** 4, 777-792.

Shiller, R. (2008). *The Subprime Solution*. Princeton: Princeton University Press.

Siu, A. and Wong, Y.C.R. (2004). Economic Impact of SARS: the Case of Hong Kong, *Asian Economic Papers*, **3,** 1, 62-83.

Solnik, B., Bourcrelle, C. and Le Fur, Y. (1996). International Market Correlation and Volatility, *Financial Analysts Journal*, **52,** 5, 17-34.

Thaler, R. and Sunstein, C. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. New Haven: Yale University Press.

Thoma, M.A. (1994). Subsample Instability and Asymmetries in Money-Income Causality**,** *Journal of Econometrics*, **64,** 1-2, 279-306.

Veldkamp, L. (2006). Information Markets and the Comovement of Asset Prices, *Review of Economic Studies*, **73,** 3, 823-845.

Wang, K., Zhou, Y., Chan, S.H. and Chau K.W. (2000). Over-Confidence and Cycles in Real Estate Markets: Cases in Hong Kong and Asia, *International Real Estate Review*, **3,** 1, 93-108.

Weimer, D.L. and Wolkoff, M.J. (2001). School Performance and Housing Values: Using Non-Contiguous District and Incorporation Boundaries to Identify School Effects, *National Tax Journal*, **54,** 2, 231-253.

Yuan, K. (2005). Asymmetric Price Movements and Borrowing Constraints: A Rational Expectations Equilibrium Model of Crises, Contagion, and Confusion, *Journal of Finance*, **60,** 1, 379-411.

Appendix

Appendix I
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 heterogeneities.

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 as to capture any non-linear effects. 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, the traditional approach of introducing neighborhood attribute variables, such as swimming pools, proximity to water, proximity to local and 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

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[43] The EPRC provides two numbers of area data: the gross and the net areas. 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 potential sources 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 is based on the parameters of hedonic pricing models, more efficient.

‘observed’ characteristics (e.g. Village Garden and Parc Oasis). This necessarily implies that their returns which are based on 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 in which each 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 in house prices that seems to be far from expected, with respect to the recorded attributes of the housing units. However, casual exclusion of potential outliers could be risky in creating biases in index construction, if we eliminate too many observations. A huge amount of effort has to be made to check or correct every suspicious case and avoid incorrect exclusions, 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 transaction records with a 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 have any transactions, as their market is relatively thin. Following the practice of past studies, the price of a zero-transaction month is set equal to the transaction price of the 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 a possible scale effect.

Appendix II
Detailed Results with Regards to the Trading Volume

As we circulated our paper, there have been many 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: an augmented Dickey–Fuller (ADF) test is used to check the stationarity of trading volume at a 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 δ = 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 that Y is not stationary.

Our impression is that, for several estates, "non-stationarity" comes from a few months of un-usually high trading activities. This will be the case for the Hong Kong Gold Coast, Sea Crest 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 two variables. A correlation coefficient of 0 means that there is no linear relationship between 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. Hence, the technique of *rolling window estimation* tries to add the time-varying property into this commonly used statistic.

Rolling Window Estimation

Let x_i be the realized value of the 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 the end of the 24-month window),

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

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

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

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

Hence, a count of correlation coefficients that are (1) positive, (2) negative, (3) significantly positive and (4) significantly negative is obtained; also, 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 is applicable in our study to the Hong Kong residential property market. In a standard single-factor capital asset pricing model (CAPM) framework with a zero risk-free rate, estate *i*’s excess return in period *t* can be expressed as:

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

where β_{im} is estate *i*’s sensitivity to the market return (R_{mt}) and $\tilde{\varepsilon}_{it}$ 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 components.

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

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. β_{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) $$\varepsilon_{it} = (\beta_{im} - 1) R_{mt} + \tilde{\varepsilon}_{it}$$

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

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

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

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

$$\text{VAR}_t = \text{MKT}_t + \text{IDIO}_t$$

Appendix V
Further Results on the Distribution of (Sample) Correlations

In the main text, we have focused 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*! This 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 the 1999 M1. It then declines and becomes close to zero since 2001 (i.e. the distribution becomes

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[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*.

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

approximately symmetric). The following graphs provide a visualization of this discussion.

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

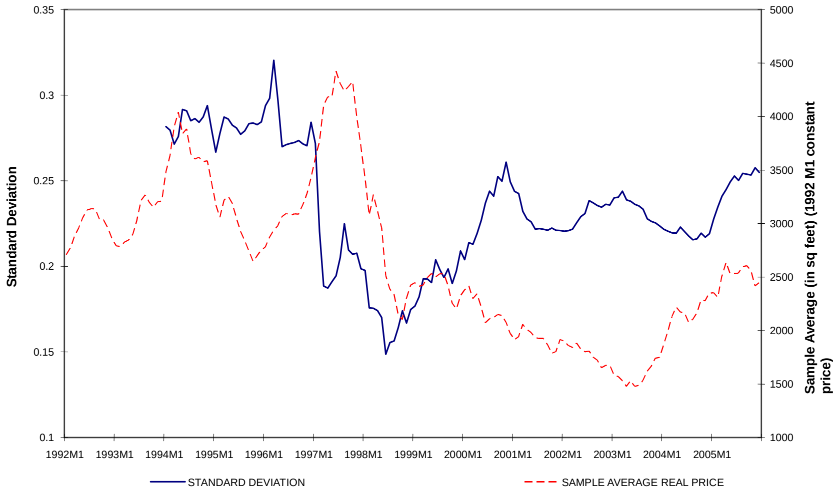
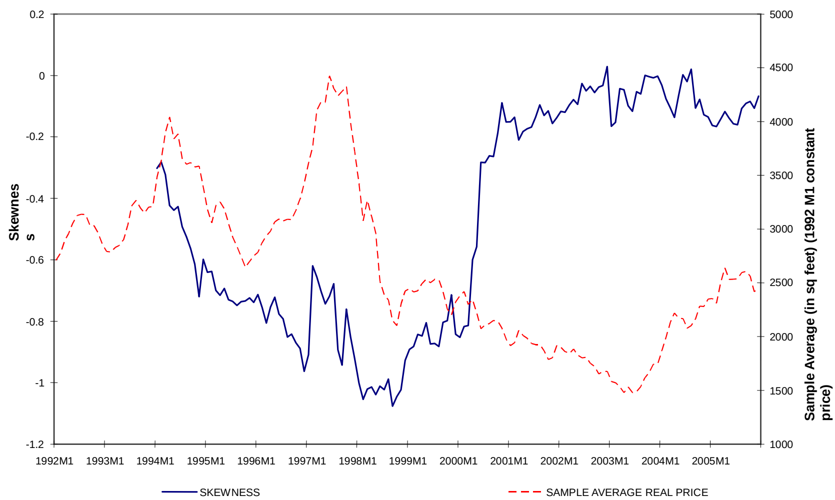


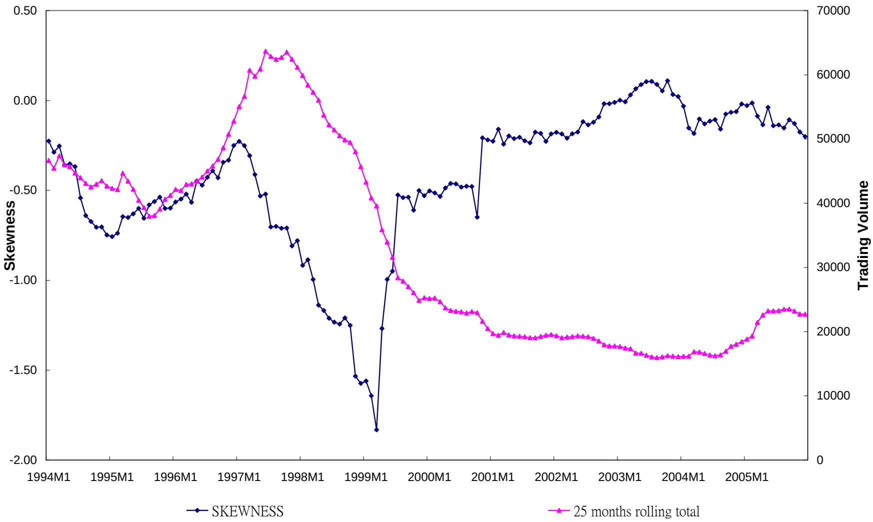
Figure A2-2 Skewness - Rolling Window Correlation Coefficients for Full Sample Price



In the text, we have 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 is almost restored to a value of -0.25, where the skewness series begins. As in the case of price, the skewness of correlations among the trading volume of estates is strongly related to the mean counterpart, with a correlation of -0.89! The following figures provide a visualization of this discussion.

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 have focused 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 correlations (i.e. standard deviation and skewness) and the ratio of IDIO to VAR. The standard deviation co-moves with the ratio of IDIO to VAR until the end of 2000. On the other hand, the skewness measure of correlation coefficients closely moves 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 a visualization of this discussion.

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

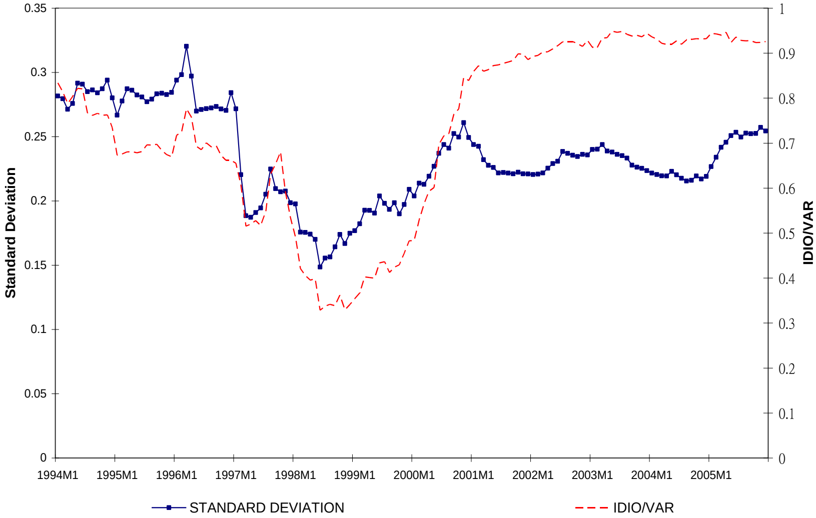


Figure A2-6 Variance Ratio and Skewness of Correlations - Full Sample

Appendix VI

Decomposition of the Mean Correlations

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

$$S = \sum_{i=1}^{n} \sum_{j=1, i \neq j}^{n} \rho_{i,j} / N,$$

where $\rho_{i,j}$ represents the correlation between estates 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 the 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 a total of 6 estates; A, B, C, D, E and F. Let us further assume that estates A, B and C belong to group 1 and estates D, E and F belong to group 2. In this case, we can write

$$\begin{aligned} S &= \sum_{i \in G_1} \sum_{j \in G_1, i \neq j} \rho_{i,j} + (\sum_{i \in G_1} \sum_{j \in G_2} \rho_{i,j} + \sum_{i \in G_1} \sum_{j \in G_2} \rho_{j,i}) + \sum_{i \in G_2} \sum_{j \in G_2, i \neq j} \rho_{i,j} \\ &= 2*\{(\rho_{A,B} + \rho_{B,C} + \rho_{A,C}) + \\ &\quad \rho_{A,E} + \rho_{A,F} + \rho_{A,G} + \rho_{B,E} + \rho_{B,F} + \rho_{B,G} + \rho_{C,E} + \rho_{C,F} + \rho_{C,G}) \\ &\quad + (\rho_{E,F} + \rho_{E,G} + \rho_{F,G})\}, \end{aligned}$$

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 terms 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 a total of $N_1 \equiv n_1(n_1 - 1)$ correlations in the first term, $N_2 \equiv n_2(n_2 - 1)$

correlations in the third term, and $N_{12} \equiv n_1 \bullet n_2$ 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 group 1 and the other is from group 2.

Now assume that we calculate S_1, S_2, S_3 for each window. As we roll over different windows, we can trace the changes of the mean correlations within groups as well as among groups.