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Examining structural changes in Asian offices market

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\textbf{ABSTRACT}

It is complicated to measure the effects of various economic events on office markets within a non-parameter modeling framework. In response to this issue, a non-parametric statistical method-wavelet analysis is introduced in this study. Based on this innovative technique, we not only could detect the abrupt change points with a comparatively small data sample, but also could evaluate the impact from the abrupt change points by reconstructing the wavelet coefficient/de-noising the raw data, which had never been considered in previous studies of office markets. Our empirical results suggest that the wavelet reconstruction method, to some extent, makes it easier for the detection of the existence of structural change points. More interestingly, our findings also indicate that free market economies (i.e. Hong Kong and Singapore) are mainly influenced by the effects of global events, whereas the actual (net) impact on socialist economies (i.e. Beijing and Shanghai), depends on both the openness of the economies, and the magnitude of counter domestic forces put in place.

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\section*{Introduction}

How do economic events affect real estate markets? It is one of the topics that has long been getting the attentions of researchers and policy makers alike. Loosely speaking, economic events which have significant effects on real estate markets are usually classified into two categories: global events and domestic events. It is believed that real estate markets are subjected to global economic events in market economies (Renaud, 1997). Meanwhile, in socialist economies, governments intervene in property markets in response to the impacts of similar events (Tian and Ma, 2009). In other words, the real estate markets in different economic systems are influenced by different factors. For instance, on 2 July 1997, the day after Hong Kong’s handover to China, the Asian financial crisis began. Hong Kong’s real estate market had been badly hit, with property price index having fallen by more than 30%. Even to this day, the real estate index has yet to return to its peak level prior to the handover. Meanwhile, the Chinese government responded to the financial crisis by stabilizing the Renminbi (RMB). Therefore, the non-convertibility protected RMB’s value from speculative activities on it. Besides, by maintaining the peg of RMB, China’s standing within Asia has improved. It has been reported that this policy measure effectively protected China’s real estate markets during the crisis. A study of how latent structural changes in real estate markets (i.e. housing prices), with respect to similar events, differ between free market economies and socialist economies would fill the existing knowledge gap in the literature.

It has been pointed out in a variety of studies that housing price is affected by factors such as interest rate, land supply, and inflation rate (Tian and Ma, 2009; Tsatsaronis and Zhu, 2004). Previous researches have usually concentrated on parameter models such as regression models on housing price and on the correlations between price and various factors. In order to generalize the regression analysis for practical reasons, some assumptions are needed to be set regarding the sample data. This method, however, not only overlooks the issue of multicollinearity of the sample data, but also dismisses the jumps. It is observable from the market that jumps may appear in time-series housing price index data. Moreover, the study on the magnitude of the jumps, or the impact from events, is rarely seen in real estate literature. In this paper, we intend to investigate whether or not a change appears when an economic event takes place in an office property market. More specifically, we will apply the method, introduced by Ip et al. (2004) and Donoho and Johnstone (1994), of wavelet change point detection and wavelet coefficient reconstruction techniques to study the office indices of four renowned Asian cities: Beijing, Shanghai, Hong Kong, and Singapore. One feature that distinguishes this method from the others is that it is applicable to smaller data samples within a non-parameter framework. Besides, we aim to employ the wavelet coefficient reconstruction method to explore office markets in cities under different economic systems and to find out how the latent structural changes differ among these markets. A study of which could provide a useful reference for future investigations of housing markets of other international cities.

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This paper is organized as follows. After a brief introduction, we discuss relevant literature on the approaches for detecting cusps, jumps and change points in 'Literature review' section. 'Model' section presents the wavelet analysis model for jump point detection and de-noise reconstruction. 'Empirical studies' section reports the findings, and hence identifies and discusses some important events in the corresponding points. The last section concludes the paper.

Literature review

Studies of change points

A great number of approaches have been utilized for testing structural change points (Wu and Chu, 1993; Bernier, 1994; Perron, 2005). Mathematically, Fourier transforms and statistical methods are common methods to detect change points. Rachev and Sengupta (1993) studied the "stability" properties of Laplace and a mixture of Laplace and Weibull in modeling price changes. Lombard (1988) detected cusps by a Fourier analysis. Indeed, the Fourier transform only converts the data into a signal process, whilst neglecting other information such as the location of the frequency. In other words, the method is unable to inform us the location effect within various time periods. To address this particular issue, Muller (1992) introduced a non-parametric method to estimate the location of cusp(s) and its size. This approach is closely related to the boundary kernels framework. Nevertheless, it is still hard to find a criterion to detect a jump point. Compared to the model provided by Muller (1992), Eubank and Speckman (1994) employed a semiparametric approach to detect the discontinuities in the derivatives of regression functions. They loosened the requirements of smooth higher derivatives for the function. However, similar to Muller's method, Eubank and Speckman's approach also requires a large data sample. Statistically, Andrew and Meen (2003) employed aggregate time-series data to find the relationship between house prices and transactions in the U.K., and discovered a change point during the 1990s. Lavielle and Teyssière, 2006 used the method proposed by Andrew and Meen (2003) to analyze the returns from real estate and financial investments. Lavielle and Teyssiere also considered the bivariate series of returns on FTSE 100 and S&P 500 index, and the results showed that some major changes upon economic events are detected. Another study by Strikhom (2006) focused on the US ex-post real interest rate series. He used a sequential method to determine the number of breaks in piecewise linear structural break models. Hillebrand and Schnabl (2006) concentrated on the effect of Japanese foreign exchange interventions on the volatility of the Yen/Dollar exchange rate. A change point detector was used for the segmentation of the data. Furthermore, Bourassa et al. (2009) developed a model of the repeated sale of residential single-family properties and investigated the impact of housing characteristics on the rate of appreciation. Their findings suggested that the average change in house prices is related to changes in national and local macroeconomic variables or market-wide bubbles. Nonetheless, their method only applies under the hypothesis that housing price adjustments only depend on housing characteristics as well as change in the strength of the housing market. Eliasson and Pétursson, 2009 studied the structural change in the Icelandic Housing market, with the focus mainly on the regression analysis. More recently, Hui et al. (2010a,b) presented a new abrupt change point detection method – a wavelet analysis on Hong Kong's residential real estate market. They pointed out that the detected change points are closely related to events, which are not observable directly. However, Hui et al. (2010b) only used a conservative standard for the selection of the benchmark/threshold in identifying these change points. In addition, the study did not proffer an efficient way to measure the impact of each change point.

As wavelet analysis has some desired properties, it is suitable to deal with the problems containing the information from real estate markets, which do not require any hypotheses with regard to the market (e.g. market equilibrium). Donoho and Johnstone (1994) brought about selective wavelet reconstruction technique, which generalized the traditional wavelet detection analysis using smaller samples. Wang (1995) suggested a method to detect jumps and sharp cusps in a function, which was observed with noise by checking if the wavelet transformation of the data has significantly large values (in absolute terms) across fine scale levels. The limitation of his method is probably the assumption of uncorrelated white noise about the data series. Ip et al. (2004) proposed a wavelet approach to detect jumps or cusps of a discontinuous function in the presence of a noise. They applied their method to the daily exchange rate of US dollar against Deutsche Mark from 1 August 1989 to 31 July 1991, with convincing results in which all the points detected reflected strong economic and political impacts. Compared with the three other methods, their method was the most reliable one. More recently, Lai and Huang (2007) applied wavelet transform in China's real estate stock market, but due to the lack of data support, the analysis rendered to be qualitative in nature.

Overall, wavelet analysis is a powerful and versatile tool in detecting and measuring abrupt change points by using relatively small sample data sets. In the following section, we intend to employ Ip et al. (2004) and Donoho and Johnstone (1994) in our change point analysis.

Major events from 1998 to 2009

The following global events1 are believed to have had major impacts on the real estate office market. This is followed by a discussion of specific Asian events.

Global events

1. The Asian Financial Crisis was a period of financial crisis that gripped much of Asia beginning in July 1997, and raised fears of a worldwide economic meltdown due to financial contagion. As the crisis spread, most of Southeast Asia saw slumping currencies, devalued stock markets and other asset prices, and a precipitous rise in private debt. Hong Kong was hurt by the slump, while the People's Republic of China and Singapore were less affected, although all suffered a loss of demand and confidence throughout the region.

2. The subprime mortgage crisis is an ongoing real estate and financial crisis triggered by a dramatic rise in mortgage delinquencies and foreclosures in the United States, with major adverse consequences on banks and financial markets around the globe. The crisis, which had its roots in the closing years of the 20th century, became apparent in 2007 and exposed the pervasive weaknesses in financial industry regulations and the global financial system. Approximately 80% of U.S. mortgages issued in recent years to subprime borrowers were adjustable-rate mortgages. When U.S. house prices began to decline in 2006–2007, refinancing became more difficult and as adjustable-rate mortgages began to reset at higher rates, mortgage delinquencies soared. Securities backed with subprime mortgages, widely held by financial firms, lost most of their value. The result was a large decline in the capital of many banks and U.S. government sponsored enterprises, tightening

1 The events (global base and city base) are collected from the Bloomberg Database.
the credit granted around the world. It is expected that this serious effect from U.S. would “contaminate” Asian real estate markets.

As the news of Lehman Brothers’ bankruptcy broke out in mid-September 2008, the global financial market soon fell into an abyss of pessimism, giving rise to the sharp reduction in the scale of production. From the investors’ point of view, the global financial crisis hit the real estate market the hardest, and the change point was found in Asian real estate markets.

Asian cities’ events

Singapore

In 2001, the unemployment rate of Singapore rose to a 15-year high, and 10 million square feet of office spaces were vacant due to the worst recession in the past four decades. Home price, office price and rent dropped drastically. High unemployment rate indicates that more people have to delay their homeownership plans due to the lack of a stable source of income. Housing demand is expected to decrease. In addition, high vacancy rate of office spaces would have indirect influence on housing market. Companies were expected to contract their scales, meaning that the economic depression would likely continue.

In February 2006, prices of luxury residential properties rose by 5–10% with strong demand from overseas companies. Straits Times Index rose to its highest in 6 years. The price increase in the luxury residential market would have spill-over effects on the non-luxury residential and office markets. Even though overseas companies have no interest in non-luxury residential housing and office, local investors may turn to these houses since they may consider that these houses would have higher return than luxury houses.

Beijing and Shanghai

The Severe Acute Respiratory Syndrome (SARS) appeared to start in Guangdong Province of China in November 2002. It soon spread across the nation within a few weeks’ time. Consequently, this then-unknown disease lasted for almost a year, which resulted in the death of 349 victims and the economic loss was approximately 4 billion US dollars. To some extent, this unpredictable global disaster brought forth serious adverse effects on the real estate market, triggering significant drops in the office prices in Beijing and in Shanghai.

The Ministry of Land and Resources (MLR) of China promulgated Notification No. 71 in March 2004. This notification requested that after 31 August 2004, all state-owned urban land for real estate development should be granted through either tenders or auctions. The new land transaction reform introduces a market mechanism into the land transaction process in urban China and aims to create a fair, transparent land allocation system (Ding, 2007).

In 2006Q2, the State Council launched a second round of supply-side regulations as well as regulations on foreign investment on the housing market. During that time, GOSC issued a notification urging all municipality governments to improve the housing supply structure, in order to stabilize the appreciation of housing prices. Therefore, a slow down on housing price adjustments would be expected in the long run, given the possibility that more housing units are to be supplied under the restriction on unit size (Tian and Ma, 2009).

Model

Improved model for detecting change point

As our objective is to investigate change points in the real estate office markets, consider the following non-parametric model introduced by Ip et al. (2004):

$$x(t) = s(t) + n(t), \quad t \in \mathbb{R},$$  

where $x(t)$ is the data observed from the markets, usually with the noise term, and $x(t) \in \mathbb{R}$ (real set), $s(t)$ is the true value signal, a deterministic function with finite discontinuous points and $n(t)$ is a zero-mean stationary noise. The signal $s(t)$ is assumed to possess $p$ jump points, i.e., there exists $t_1 < t_2 < \cdots < t_p$, such that

$$s(t_k - 0) \neq s(t_k + 0), \quad k = 1, 2, \ldots, p,$$

where $s(t_k - 0)$ and $s(t_k + 0)$ are the left-limiting and right-limiting values of $s(t)$ respectively and $p$ is a positive integer. Except these points, $s(t)$ is differentiable on $R$ with bounded derivatives.

The problem associated with the detection of change points is ascribed to test following hypothesis:

$$H_0 : \xi_1 = \xi_2 = \cdots = \xi_n$$

$$H_1 : \xi_1 < \xi_2 < \cdots < \xi_n$$

With unknown index $j$, $\xi_j$ stands for the expected value of the data at time $j$. However, as indicated in (1), the model is non-parametric, which means that the model is distribution free so that it is not possible to test the mean value of collected data directly. Therefore, we consider the discrete wavelet transform. Define the wavelet function

$$\psi_{j,k}(t) = 2^{j/2} \psi(2^j t - k),$$

Where $\psi(t)$ is called the mother wavelet. Then the wavelet transform of a function $s(t)$ is

$$w_{j,k} = \int_{-\infty}^{\infty} S(t) \psi_{j,k}(t) dt, \quad k \in \mathbb{Z}, \quad j = 1, 2, \ldots, \ldots$$

which will result in a sequence of wavelet coefficients. $Z$ is the integer set. Consider wavelet $\Psi(t)$ of Meyer function as defined by:

$$(2\pi)^{-1/2} e^{w/2} \sin \left(\frac{\pi}{2} w \sqrt{\frac{2}{4\pi|w|}} - 1\right) : \quad 2\pi^2 \leq |w| < 4\pi^2,$$

$$(2\pi)^{-1/2} e^{w/2} \cos \left(\frac{\pi}{2} w \sqrt{\frac{2}{4\pi|w|}} - 1\right) : \quad 2\pi^2 \leq |w| < 4\pi^2,$$

$$0 : \quad |w| \neq \frac{2\pi}{3}, \frac{4\pi}{3}.$$

Thus far, a series of coefficients through wavelet transform is acquired from formula (4). However, we still need to know the threshold (benchmark) value for the testing of the hypothesis as listed above. As such, we consider the minimax threshold rules, as introduced by Donoho and Johnstone (1994), which retain only observed data that exceeds a noise level. Let

$$\eta_M(w_j, \lambda) = w_j/|w_j| > \lambda$$

$$\eta_N(w_j, \lambda) = \text{sgn}(w_j)|w_j| - \lambda,$$

where $w_j$ is the wavelet coefficient transformed via formula (4), and $\lambda$, is the threshold value, $\eta_M$ and $\eta_N$ stand for hard threshold and soft threshold respectively, and $|a|$ stands for the abstract value of $a$.\footnote{The reason to use Meyer function in this study, unlike in Ip et al. (2004), is for practical applications, and for efficiency as continuously differentiable functions with compact support as mother wavelet are preferable (Percival and Walden, 2002).}
In the following section, we focus on the soft threshold \( h_S \) in the following section. Define the minimax quantities:

\[
\lambda_n^* = \inf_{\lambda} \sup_{\mu} \min_{n+1} \{\min(\lambda, \mu) \leq n+1 \}
\]

(8)

\[
\lambda_n^* = \text{the largest } \lambda \text{ attaining } \lambda_n^* \text{ above}
\]

(9)

Consider the analog quantities where the supremum over the interval \([0, \infty)\) is replaced by that over the endpoints \([0, \infty)\). Thus, we denote

\[
\lambda_n^0 = \inf_{\lambda} \sup_{\mu \in [0, \infty)} \min_{n+1} \{\min(\lambda, \mu) \leq n+1 \}
\]

(10)

It is quite clear that \( \lambda_n^0 = \lambda_n^* \) (Donoho and Johnstone, 1994). Then we wish to estimate the \( \epsilon^2 \)-loss to find out the minimax threshold \( \lambda_n^* \), with the following equality equation:

\[
E|\theta^* - \theta|^2 \leq \sum \min(\lambda_n^*, \theta_i) \epsilon^2
\]

(11)

where \( \theta = (\theta_1, \theta_2, \ldots, \theta_n) \), \( \epsilon \) is a constant. Then the minimax threshold \( \lambda_n^* \) should be the one that satisfies

\[
E|\theta^* - \theta|^2 \leq \lambda_n^* \epsilon^2 + \sum \min(\lambda_n^*, \epsilon^2)
\]

for all \( \theta = (\theta_1, \theta_2, \ldots, \theta_n) \)

(12)

For further detail of the above (10)–(12), see Donoho and Johnstone (1994).

Model for reconstruction

As the orthogonality of the discrete wavelet transform has a fundamental statistical consequence: \( W \) is the orthogonal transformation matrix. Hence, if \( \{s_{j,k}\} \) are the wavelet coefficients of \( (s(t))_{j=1}^{n} \) collected according to model (1), then \( w_{j,k} \) are the wavelet coefficients of \( (s(t)) \), then

\[
x_{j,k} = w_{j,k} + \varepsilon_{j,k}
\]

(13)

With the property of isometry of risk, our interest is to find an estimate \( \delta = (\delta(t)) \) in the other domain by:

\[
\delta = W^T \hat{w}
\]

(14)

Where \( \hat{w} \) and \( \delta \) obey the Parseval relation \( ||\hat{w} - w||_2 = ||\delta - s||_2 \).

In order to examine the linear relationship between these four office markets, we calculate the correlation coefficients, which are illustrated in Table 1. It is apparent that the correlation coefficients between Beijing and any one of Hong Kong, Singapore, and Shanghai office markets are quite similar, which means, any of these three cities is nearly uncorrelated (the perfect correlated coefficients is 1). On the contrary, Shanghai is closely correlated to Hong Kong as well as to Singapore. Hong Kong shows a perfectly correlated status with Singapore, which coincides with our initial discussion above.

**Table 1**

|                | Beijing | Shanghai | Hong Kong | Singapore |
|----------------|---------|----------|-----------|-----------|
| Beijing        | 1       |          |           |           |
| Shanghai       | 0.351585| 0.284251 | 0.249342  |           |
| Hong Kong      | 1       | 0.787262 | 0.71724   | 0.902872  |
| Singapore      | 1       | 0.351585 | 0.284251  | 0.249342  |

Second, Beijing and Shanghai are emergent markets in a developing country, so much so that they are being called the frontline cities in China (Liu et al., 2003), where the business and real estate markets are vibrant. As a result, real estate office markets of these two Chinese cities may have sensitive market reaction towards various events. Hong Kong and Singapore are the developed markets that respond to these events quickly. As such, a study of these markets provides a good understanding of real estate office markets between developed regions and developing regions. In addition, an investigation of the jump points hidden in the real estate office markets is to be carried out as well.

The relationship between office price indices of four selected Asian cities (Beijing, Shanghai, Hong Kong, and Singapore) from the 1st quarter of 1998 to the 2nd quarter of 2009 is also examined in this section. The reason to choose the office price index attributes to the fact that changes in office real estate markets are much more sensitive than those in stock markets. In fact, office real estate markets are often subjected to unemployment rate, foreign investment, and government policies (Tse, 2001; Hui and Yu, 2008). Office price lags behind stock market by about three months (Hui et al., 2007). So the use of quarterly data is considered both reasonable and feasible for our data analysis. To facilitate our analysis, it is assumed that the detected change point, corresponding to the real estate market, is found at least three months after an event takes place. In addition, we attempt to analyze the wavelet coefficients for each city and then to illustrate that the change points are closely related to either local or global events. The historical data of these four Asian cities are collected from Jones Lang LaSalle.4

Fig. 1 shows the time series plot of the office price indices of the four cities. It is quite obvious that the trends of Singapore’s and Hong Kong’s indices were quite similar. Both began with a slightly downward trend, followed by a short period of fluctuations that took place before a marked upward trend. After that, both indices noticeably fell from their peaks around 2008Q3. In contrast, the indices of Shanghai and Beijing seem to have maintained a relatively stable trend.

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**Discussion and findings**

It is shown that change points hidden in office real estate market are not easy to detect via observations. On utilizing the non-parametric change point method-wavelet analysis, the data for each office real estate market was transformed to wavelet coefficient. For coefficients that significantly pass through the

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3 http://www.forbes.com/pictures/gg45ejhmd/1-singapore/#gallerycontent

4 The source is from the website from Jones Lang LaSalle: http://www.joneslanglasalle.com/Pages/Home.aspx
Table 2
Change point coefficient.

| Time           | Beijing | Shanghai | Hong Kong | Singapore | Events |
|----------------|---------|----------|-----------|-----------|--------|
| 1998Q3–1999Q2  | √        |          |           |           | (1)    |
| 2000Q3–2000Q4  | √        |          |           |           | (2)    |
| 2003Q3–2003Q4  | √        |          |           |           | (3)    |
| 2005Q1–2005Q2  |          |          |           |           | (4)    |
| 2006Q3–2006Q4  |          |          |           |           | (5)    |
| 2007Q1–2007Q2  |          |          |           |           | (6)    |
| 2007Q3–2007Q4  |          |          |           |           | (7)    |
| 2008Q1–2008Q2  |          |          |           |           | (8)    |
| 2008Q3–2008Q4  |          |          |           |           | (9)    |
| 2009Q1–2009Q2  |          |          |           |           | (10)   |

Note: The symbol “√” indicates that at least one abrupt change point happen during the corresponding period.

 benchmark (minimax threshold), they are regarded as structural change points. These change points represent the statistical landmarks that are over the chosen threshold value. The current wavelet technique can detect multiple change points, if they exist. This technique is much superior to that of Cannarella et al. (2012) since they allow to detect only two change points.

The detected abrupt change points are roughly 3–12 months behind the occurrence of certain events (Table 2), which coincide with the findings of Hui et al. (2010a), and are in line with the general belief. Surprisingly, for each event, there is no consistent effect for the four office markets during the same period, which somewhat differs from the result in Ip et al. (2004). This outcome is mainly due to the fact that these four markets are within different economic systems. For instance, Shanghai and Beijing are planned economies, while Hong Kong and Singapore are market economies. Specifically speaking, before 2008, change points are found in the Beijing and Shanghai office markets. During this period, Chinese office real estate markets had experienced Severe Acute Respiratory (SARS) in 2003, and later the “State Council’s eight points” and “The regularity notification with regard to further strengthen and stabilize the foreign direct investment in real estate”. The latter two reflect the Chinese government’s determination to regulate the real estate market, especially the office market. Hence, it is not surprising that these abrupt change points are primarily found between 2003 and 2007. In contrast, without direct government intervention in their respective property markets, Hong Kong and Singapore were comparatively more susceptible to economic events such as the two financial crises in 1997 and 2008 respectively. As a result, a series of change points have been detected during this period (Fig. 2).

As illustrated by the de-noise plot of the four office markets (Fig. 3), however, an apparent and sharp downturn can be observed for Beijing’s office market in 2003Q2, as compared to the
original data plot. De-noise technique is used to estimate the true value signal $s(t)$. The comparison in Fig. 3 is in fact the comparison between $x(t)$ and the estimation of $s(t)$. Few differences between these two graphs emphasize that traditional methods cannot detect much more change points using de-noise data compared with either original data. It is showed that the wavelet analysis is preferable. This indicates that the non-parametric non-linear smoothing process alternatively strengthens our belief that the detected change points during that period are the structural change points. Those structural changes result in long-term effects to office markets.

Conclusion

As wavelet analysis has properties for detecting the abrupt change points in a non-parameter non-linear modeling framework, it is much more powerful and thus more useful to investigate the structural changes in office markets than traditional statistical methodologies such as linear regression models. Also, as the wavelet analysis is applicable to smaller data samples, it allows for the exploration of newer office markets such as those in Chinese cities. Our study has compared the change points’ effects (Fig. 3) of various cities under different economic systems and the findings point out that some change points in the office markets of four Asian cities have been detected and that they occurred 3–12 months after significant global and local events. The office sector is not significantly affected by the 2008 financial crisis in Beijing and Shanghai. Yet, government interventions in the economy are not able to deal with non-financial, local crises such as the outbreak of epidemics. In contrast, free market economies (i.e. Hong Kong and Singapore) appear to be more susceptible to global events/crises, but subsequently would trigger a self-adjusting mechanism to recover from a changing environment.

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