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A continuous wavelets approach of China opening reforms effects on relationships between mainland Chinese stock exchanges and Hong Kong

Yang Mestre Zhou
MRE, University of Montpellier

Roman Mestre
MRE, University of Montpellier

Abstract

This paper analyses the relationships between the Chinese mainland markets (Shanghai and Shenzhen) and Hong Kong market considering the important reforms periods from 2001 to 2005 with the Non-Tradable Share reform. We use standards econometrics methods of causality and cointegration and the wavelets coherence and phase methods on daily Chinese stock markets prices from 1993 to 2017. By using the causality test and co-integration analysis, we find that the NTS reform modifies the linkages between three markets. SSE becomes the leader of the Chinese markets. The wavelets allow to analyse time-frequency correlation and Instantaneous Time Lag interaction between pairwise variables. Results confirm that the opening reforms increased the level of correlation both in long and short run between mainland market and Hong Kong. In addition, the influence of mainland markets on Hong Kong is increasing but Hong Kong still strongly affects them especially during crisis time and at long run. The wavelets approach finally highlight those relationships between Chinese markets are multidimensional and dependent to the horizon of study.

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Contact: Yang Mestre Zhou - christinezy.yz@gmail.com, Roman Mestre - roman.mestre@live.fr.
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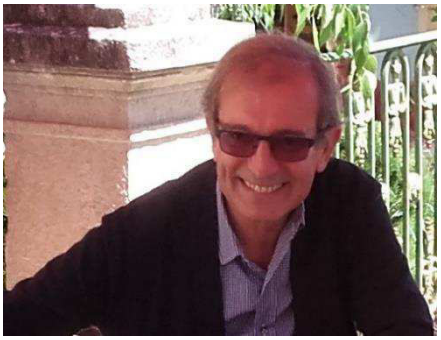

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Special issue “In memory of Professor Michel Terraza”

1. Introduction

In an environment of economic globalization, Chinese stock markets become more and more open and bring new investment opportunities at each step of its liberalization process. However, there are three main Chinese stocks markets with different rules according to foreign investment. ShenZhen Stock Exchange (SZSE) and Shanghai Stock Exchange (SSE) located in Mainland China and the Honk Kong Stock Exchange (HKSE). The two continental stocks markets were created during the beginning of 90s. Hong-Kong came back to China in 1997 with a specific economic status. Hong Kong is more open to the foreign investors and rules are closer to international standards, whereas SSE and SZSE are still relatively closed with capital flows control and limited foreign investors at the beginning.

The relationships between the three Chinese markets are influenced by the Chinese policies on the Economic Reform and Opening up processes following different development phases. The first step of the Chinese Economic Reform is realized by Deng Xiaoping in 1978-1979 with a project focused on a progressive opening up of the Chinese society through economic and financial liberalization. In the 1980s and especially at the beginnings of the 1990s, Government decides to modernize the economy and the Chinese society into a socialist market economy allowing establishment of the first Special Economic Zone (SEZ) in ShenZhen (near the Hong Kong Border) and opening of the City of Shanghai to foreign investments under conditions. During this period, the Shanghai and the ShenZhen Stock Exchanges was created in 1990 to allow State Owned Enterprises to raise funds through IPOs in a move to liberalize economy. At the beginnings of the 2000-decade, China joined the World Trade Organization (WTO) in December 2001 as a first step to world integration. Concerning the case of Hong Kong and Macau, China and the Governments of these two Special Administrative Regions signed in 2003 the Closer Economic Partnership Arrangement (CEPA) to ease and promote economic exchange between Mainland China and Macau and Hong Kong cities.

Despite the efforts realized, the financial market remained closed as the stocks are divided into A-shares labeled in Renminbi Yuan (RMB) exclusively tradable by domestic investors and B-Shares libeled in US Dollars and tradable by domestic and foreign investors. To gradually ease foreign access to Chinese stocks markets, China has started to implement a program “Qualified Foreign Institutional Investors” (QFII) in 2002-2003, which allow some foreign institutional investors to buy A-share denominated in RMB in the two China’s mainland stock exchanges. In the same way, in 2006-2007, the “Qualified Domestic Institutional Investors” Program (QDII) is launch to allow Chinese institutions to access foreign investment products.

However, the vast majority of the shares in circulation are “Non-Tradable Shares” (NTS) indicating that holders can’t publicly exchange them into the Market. This situation is specific to the mainland China A-share market. This point represents a severe limitation to the opening process and for a full implementation of a greater liberalized stock markets as NTS are not competitive (by limiting the float) compare to standard shares for potential investors (Foreign or domestic).

In order to make the Chinese mainland markets healthier with stable development and attract more foreign investors, the Chinese government has established the Split-Share Reform or Non-tradable Share (NTS) Reform at the end of 2005. In order to eliminate the differences in the shares-exchanges system, the China Securities Regulatory Commission (CSRC) launch the reform for NTS to achieve an objective: for a same-share there are the same right and the same profitability. "NTS reform allowed shareholder to profit immediately." (Yeung 2009). It's a milestone in the process of the modernization of Chinese market; it can better understand the overall institutional mechanisms that promote China's economic growth. (Yeh *et al* 2009). The trading of equities is facilitated and simplified under the new mechanism established and a transition plan to gradually open the market (Joyce 2008). Others legislative laws (such as the Company Law or the Securities Law) was established to support the NTS reform in a legal framework. The split share reform is one of the most important reform as it eases trading of all Chinese shares reinforcing all previous reforms in their operative implementations.

Reforms made during the period 2001-2006 are the pillar of the Chinese financial opening up and after this period the Chinese mainland stock market started their gradual integration in the global financial system. In parallel, another important step in the opening process is the internationalization of the Renminbi Yuan through the Hong Kong Stock market interface started in 2004 when RMB deposit in Hong Kong is allowed. In 2007, the offshore RMB Bond Market is established in Hong Kong. Then Hong Kong represents a market to buy offshore Yuan and an important channel to invest in Mainland China as in 2011 the Chinese Government launched the Renminbi Qualified Institutional Investors Program (RQFII) allowing overseas institutional investors to buy yuan denominated shares via Hong Kong. The role of Hong Kong as a gate to Chinese securities markets is reinforce with the Shanghai Hong Kong Stock Connect (2014) and ShenZhen Hong Kong Stock Connect (2016) Programs. These Programs allows qualified investors to enter both mainland and Hong Kong market to trade stocks with their local institutions (brokers and clearing houses) under daily and global quotas. The gradual and relatively quick opening of Chinese Financial system leads to a stronger connection of mainland markets with Hong Kong appearing as the gate to mainland markets. Mainland Chinese stocks markets attract more and more investors while gradually opened up to better adapt the financial liberalization environment, and so the relationship with Hong Kong can change over time. After this period, the Shanghai Stock Exchange progressively developed to being ranked in the top 5 world most important financial market.

They are an interesting subject of studies in many fields concerning Chinese markets such as volatility analysis, corporate finance and world integration. Many papers focus on China market links with other international financial markets. Wong et al (2004) analyze the co-movements of emerging and developed countries; they find that Hong Kong stock market is cointegration with the United States and the United Kingdom. Gupta and Guidi (2012) found no long-run relationship between India and Hong-Kong. These papers consider Hong-Kong market to represent China as it is the only market opened. He et al (2015), Luo and Schinckus (2015), and Luo and Ye (2015) focused on Shanghai Stock Markets world integration and co-

movement with US markets. They conclude that the opening up process tends to increase the correlation of SSE with others major stock markets (especially the US). Johnson (2010) indicated that Chinese markets integration increases significantly after the reform period but at a slow pace and starting from a very low level.

Few papers analyze the effect of opening reform on Chinese stocks markets. Yeung (2009) concludes that the reform will improve the equity liquidity and the market's stability in the long-term. Guo et al (2016) find that the reform improves the corporate finance structure. Beltratti at al (2016) highlight that there is an announcement effect generating positive abnormal returns. The previous studies are based on stocks performances before and after the reform but not on the effect on the markets linkages. However, Chang et al (2014) and Wang et al (2016) conclude that the Stock Connect Programs strengthened the connection between the mainland markets and Hong Kong leading to mutual influence and transmission channel of shocks at each significant advancement of the opening process. Li and Chen (2020) indicate that the Sock Connect Programs don't significantly affect daily co-movements between mainland and Hong Hong but improved the weekly co-movements.

Considering the rising power of Shanghai and ShenZhen in the World top markets, the question of the ''leaderships'' interactions of each stock exchanges as influencer or influenced, is determinant to analyses the structure of Chinese stock exchange.

The main goal of this paper is to merge the two problematics by analyzing the impact of the opening reform process on the market linkages according to various investment terms (short, medium, long run) thanks wavelets analysis. The choice of the wavelets tools is justified by their abilities to decompose time series according various frequency components while keeping the time information (see. section 2.3). Then, we analyze the co-movement of the Chinese market considering the reform period in order to identify the degree of integration and the leadership relationships between these markets.

The remainder of this study is organized as follow. In a first part, we briefly present the current literature focusing on the relationships between Chinese markets, while in a second part we present the data and methodology used in the paper. The third part provides the empirical finding obtained with standard econometrics approach and the fourth part is focusing on the time-frequency modelization of the relationships.

2. Literature review

In the context of China Opening up, few papers focused on interactions and relationships between the three Chinese markets. Lu and Zhu (2001) find that HKSE is not linked with mainland markets with Granger causality. Wang and Xu (2003) confirm partially this result; the volatility of HKSE is not dependent on Mainland Markets. The influence of Chinese markets is not significant (but they suppose that it could increase in the future). Hu and Lv (2008) indicate that HKSE and SSE "are isolated and separated". However, other studies highlight strong linkages between Chinese stock markets. Zhu *et al* (2004) find HKSE Granger causes Shanghai volatility. And there is feedback between Shanghai stock market and Shenzhen stock market. Shi (2002) and Li (2009) show that SSE and SZSE are co-integrated and conclude that there is a long-run relationship. Wang and Yu (2004) analyze the impact of Asian Crisis in 1997 and they find that before SSE and SZSE influence HKSE and after crisis linkages are tighter with mutual influences. Guo and Wang (2009) find similar results. Wong and Chen (2011) find that there is no relationship at long-run but at short-run linkages are stronger. The previous studies are interesting but they are focused on the Hong-Kong reunification to China in 1997 and the Asian Crisis of 90's. They do not consider the important reforms period from 2001 to the split-share reform at the end of 2005.

These reforms launched to liberalize and opened mainland markets to overseas investors can affect the relationships between Mainland and Hong Kong markets. Su et al (2007) highlight that the CEPA strengthened the relationship between the Stock markets as a cointegration relationship started after the establishment. Qiao et al (2008) confirmed these results adding that a bi-causal relationships appeared and the reform and QFII program accelerated the integration of Mainland markets through Hong Kong. Qiao et al (2008) extended the previous results by indicating that the QDII program generated a leadership from Mainland Market to Hong Kong one. The causation relationship leadership are studied by Shi et al (2011) and Chang (2015) which concluded that after the 2008 crisis the influence of Mainland Markets on Hong Kong become significant generating a bi-causal relationship increasing in intensity in short run. Chang et al (2014) and Wang et al (2016) conclude that the Stock Connect Programs reinforced the effect of Mainland markets on Hong Kong while keeping a mutual influence. However, Li and Chen (2020) indicate that the Sock Connect Programs don't significantly affect daily co-movements between mainland and Hong Kong but improved the weekly co-movements.

It appears that reforms greatly affect the relationship between Chinese market but at different levels. We propose in this paper to analyze the effect of opening reforms on Chinese markets in terms of integration and leadership while considering the multidimensional nature of the linkages thanks wavelets coherence and phase. Many studies used wavelets approach to measure co-movements between financial variables distinguishing short and long run. Rua and Nunes (2009) used wavelets coherence and phase to assess the co-movements across various frequencies range between major international markets highlighting the useful to analyse interdependencies. Many studies are based on wavelets approach to model the dynamic co-movement between financial assets such as Commodities and markets indices (Vacha and Barunik 2013, Aguiar-Conraria and Soares 2014, Bekiros et al 2016, and

Kahraman and Unal 2019). In addition, the wavelets Phase analysis allow study of lead-lag effect through the Notion of Instantaneous Time Lag (ITL) which convert phase difference between two variables into a time shift (Aguiar-Conraria et al 2019). The wavelet approach is detailed in the following section.

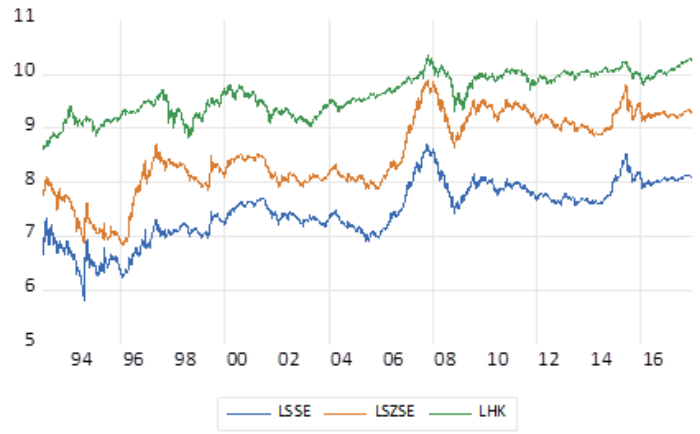
3. Data and Methodology

3.1 Data presentation

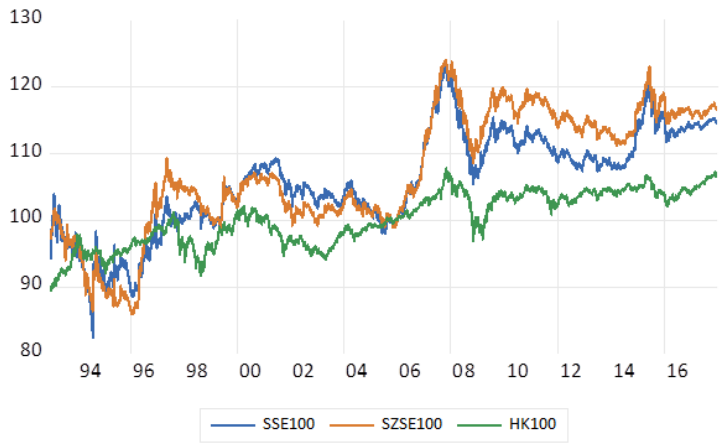
In this paper, we use the three Chinese markets indices, the SSE Composite Index (called SSE), the SZSE Component Index (called SZSE) and the Hang Seng Index (called HKSE) for the daily period from January 1, 1993 to December 29, 2017 (Figures 1). The data are obtained from Yahoo Finance database. All the indices are analyzed in logarithms, called LSSE, LSZSE and LHK, to compute log-returns having theoretically better normal distributions features than stock prices characteristics. By representing the main Chinese indices in points with a base 100 at the end of 2005 (12/31/2005), we clearly visualize the situation after and before this date supposing an important break due to a greater opening up. Figure 1.1 illustrates the stock prices movement among Chinese markets.

Figures 1: Chinese markets indices: 01/01/1993-12/29/2017

1.1 Stocks Markets indices in lo-form



1.2 Stocks Markets Indices base 100 (12/31/2005)



We test the stationarity of these indices by Unit Root Test for all the previous logged variables. In this study, we use the ADF Augmented Dickey-Fuller Test (1979-1981) and PP Phillips-Perron test (1988) following the Cem Ertur strategy[1]. We use these two tests to asset the non-stationarity nature of the series considering potential autocorrelation and heteroscedasticity issues. According to the test statistics in Appendixes Table A1, we can conclude that SSE, SZSE and HKSE (in logarithms) have a unit root at the 1% risk level and the strategy indicates the three series are order 1 integrated I(1). The fist differences filter is used to stationarize the series generating the returns of the indices, noted DLHKSE, DLSSE and DLSZSE.

To examine the short-run lead-lag interactions and the long-run co-movements between the three Chinese markets, we perform the Granger's Causality Test (1969) and Co-integration analysis (Engel and Granger 1987, Johansen 1995). The Granger Causality test is based on VAR(p) model on stationary variables where p is determined by minimizing an Information Criterion (SIC). To analyze cointegration, we use the Trace Test proposed by Johansen (1988-1995) to determine the number of co-integration relation between several series. The results of these standard approaches will be extended and complemented using a time-frequency analysis wavelets tools.

3.2 Wavelets Coherence and Phase

The Wavelets are extension of the spectral analysis of time series allowing to decompose a chronic in the time-frequency space. Wavelets decomposition was firstly developed by Meyer et al (1986), Grossmann and Morlet (1984), Meyer (1990) and extended by Mallat (1989-2001-2009) and Daubechies (1992). We distinguish two forms of wavelets decomposition processes: the discrete called Maximal Overlap Discrete Wavelets Transform (MODWT) and the Continuous one called CWT (Continuous Wavelets Transform). The main difference between MODWT and CWT are the type of wavelets used, the accuracy in the frequency scale and then the computational time. MODWT are based on a dyadic scale decomposition in which frequencies components are ranked into wavelets frequency bands of length equal a multiple of 2 only. While the CWT is finer and more accurate to distinguish frequencies. In addition, CWT provides cross-transform of two variables useful to analyses interaction and between them across time and frequencies.

The CWT is based on a wavelets-mother $\psi(t)$ serving as a filter to extract information from a time series $x(t)$ of length N. This function will be shifted by , a time parameter, and dilated by s, a frequency scale parameter, generating the wavelets family $\psi_{\tau,s}(t)$ composed by "wavelets-daughters" representing each version of $\psi(t)$ according to τ and s.

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right)$$

[1] More details on this procedure are available in Terraza and Bourbonnais book (see references).

The initial chronic $x(t)$ will be projected in the $\psi_{\tau,s}(t)$ generating the wavelets coefficients, $W(s,\tau)$. These coefficients represent the variations of $x(t)$ around an area around $t \mp \tau$ with a frequential length s.

$$W(s,\tau) = \int_{-\infty}^{+\infty} x(t) \frac{1}{\sqrt{s}} \psi^* \left(\frac{t-\tau}{s}\right) dt$$

$\psi^* \left(\frac{t-\tau}{s}\right)$ the complex conjugate of $\psi_{\tau,s}(t)$.

Then, the CWT of $x(t)$ generates multiple sub-chronics of same length N at each frequency scale. The invers process called ICWT (Inverse Continuous Wavelets Transform) allow to reconstruct the initial $x(t)$ from all the wavelets coefficients.

$$x(t) = \frac{1}{C_\psi} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \psi_{\tau,s}(t)\, W(s,\tau) \frac{d\tau ds}{s^2}$$

The previous equation of ICWT assume that the expression C_ψ is non-nul and lesser than $+\infty$. This condition ensures the condition of existence or admissibility of the wavelet mother (Calderon 196, Daubechies (1992):

$$C_\psi = \int_0^{+\infty} \frac{\left|\widehat{\Psi}(f)\right|^2}{f} df < +\infty$$

f is the frequency and $\widehat{\Psi}(f)$ the Fourier's transform of wavelets-mother.

This condition indicates and is respected when the wavelet-mother is a zero-mean and square norm function, then the variance of $x(t)$ is preserved during the process of decomposition and reconstruction. In this paper, we use the complex Morlet wavelet $\psi_M(t)$ as she is a good balance between time and frequency representations.

$$\psi_M(t) = \pi^{-1/4} e^{if_0 t} e^{\left(-\frac{t^2}{2}\right)}$$

With $i^2 = -1$ and f_0 the non-dimensional frequency equals to 6 to satisfy the condition on C_ψ.

From a CWT based on the Morlet Wavelets, we define the notion of Wavelet Coherence which is similar to the squared correlation and useful to visualize co-movement between two chronics $x(t)$ and $y(t)$ as Grinsted et al (2004) show. The two time series are decomposed by CWT providing their respective wavelets coefficients $W_x(s,\tau)$; $W_y(s,\tau)$. So, we can compute a time-frequency covariance called the cross-wavelets decomposition $SW_{xy}(s,\tau)$:

$$SW_{xy}(s,\tau) = W_x(s,\tau) W_y^*(s,\tau)$$

$W_y^*(s,\tau)$ is the complex-conjugate of $W_y(s,\tau)$.

The formula of the wavelets coherence, $WQ(s,\tau)$, between $x(t)$ and $y(t)$ is similar to the R^2 one as the ratio of covariance and variance products.

$$WQ(s,\tau) = \frac{\left|G(s^{-1}.SW_{xy}(s,\tau))\right|^2}{G(s^{-1}.|W_x(s,\tau)|^2).G(s^{-1}.\left|W_y(s,\tau)\right|^2)}$$

G is a smoothing time-frequency operator

The time-frequency smoothing is required because the coherence coefficients are complex as indicated by Torrence et Compo (1998). The coherence coefficient $WQ(s,\tau)$ are between 0 and 1 at each time t and frequency scale s.

The wavelets Phase difference (or simply Phase) is a complementary notion to the coherence as it contains information on the leadership and sign of the relationship between $x(t)$ and $y(t)$. The phase difference function, $\theta_{x,y}(s,\tau)$, is the arctangent of ratio of the imaginary part and real part of the cross-transform $SW_{xy}(s,\tau)$:

$$\theta_{x,y}(s,\tau) = arctan(\frac{\Im(SW_{xy}(s,\tau))}{\Re(SW_{xy}(s,\tau))})$$

According to the value of the Phase difference between $-\pi$ and π we can study the sign and the leadership of the relation between $x(t)$ and $y(t)$ as follow:

- $\theta_{x,y}(s,\tau) \in \left[0,\frac{\pi}{2}\right]$: $x(t)$ and $y(t)$ move together *in phase* so they are positively correlated. In this case, $x(t)$ leads $y(t)$.
- $\theta_{x,y}(s,\tau) \in \left[\frac{\pi}{2},\pi\right]$: $x(t)$ and $y(t)$ move together *in anti-phase* so they are negatively correlated. In this case, $y(t)$ leads $x(t)$.
- $\theta_{x,y}(s,\tau) \in \left[-\frac{\pi}{2},0\right]$: $x(t)$ and $y(t)$ move together *in phase* so they are positively correlated. In this case, $y(t)$ leads $x(t)$.
- $\theta_{x,y}(s,\tau) \in \left[-\pi\ ,-\frac{\pi}{2}\right]$: $x(t)$ and $y(t)$ move together *in anti-phase* so they are negatively correlated. In this case, $x(t)$ leads $y(t)$.

The Phase Difference values can be converting in its time representation called the Instantaneous Time-Lag (ITL) as follow:

$$ITL_{x,y}(s,\tau) = \frac{\theta_{x,y}(s,\tau)}{2\,\pi\,\mathrm{f}} \approx \frac{\theta_{x,y}(s,\tau)}{2\,\pi\,\frac{1}{\mathrm{s}}}$$

The Phase and ITL are close to concept of causality in a time frequency space. The more the series are in phase the more their cycles strongly comove and are synchronized. The ITL is useful to translate the phase value in a time lags to identify which variable's cycle predates the cycle of the other one.

From the Coherence and the Phase, we can define a time-frequency correlation coefficient as follow:

$$\rho_{s,\tau} = \vartheta_{s,\tau} * WQ(s,\tau)^{1/2}$$

With $\vartheta_{s,\tau}$ a phase parameter providing the sign of the correlation (Mestre and Terraza, 2018). $\vartheta = 1$ when chronics are in phase $\left|\theta_{x,y}\,(s,\tau)\right| \in \left[0, \frac{\pi}{2}\right]$ and $\vartheta = -1$ when chronics are in anti-phase $\left|\theta_{x,y}\,(s,\tau)\right| \in \left[\frac{\pi}{2}, \pi\right]$.

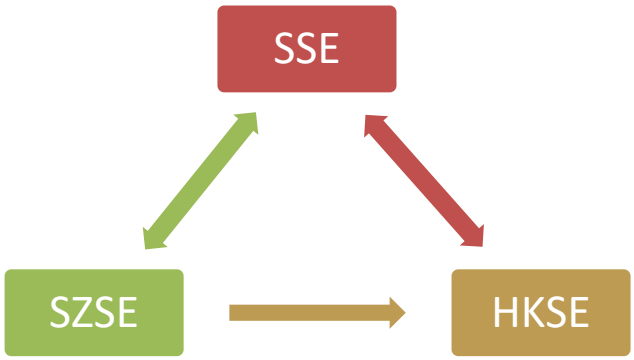
4. Empirical Finding: Causality and Cointegration

4.1 Granger causality and Cointegration on overall 1993-2017 period

In the first section, we present the results for the Bivariate Granger Causality Tests with the three stationary series. We consider the lags from 1 to 5 in order to appreciate the causality in a financial week. Results are illustrated in Figure 2 and in Table A2 in Appendixes.

We find that there are a bi-causality or feedback effect between SSE and SZSE and between SSE and HKSE. The relationship between SZSE and HKSE is not clearly explicit, SZSE influences HKSE but the feedback effect (to HKSE from SZSE) is not significant from 1 to 3 lags but the fifth lag results indicates that HKSE Granger cause SZSE at 5% risk level.

Figure 2: Granger Causality results



Previously, we find that all the series are I(1) (without constant), so we build the test on this structure and on a VAR(P) model selected by minimizing the Schwarz Criterion (SIC). On this basis, we select the VAR (1) model. Table 1 summarizes the Co-Integration Tests results.

Table 1: Co-integration Analysis Results: 1993-2017

Hypothesized/ No. of CE(s)	None	At most 1	At most 2
LSSE, LSZSE and LHKSE			
Trace Statistic	31,81	11,5	1,61
Critical Value (0,05) -Trace	29,8	15,49	3,84

The Trace test shows that there is one Co-Integration relationship between the three markets at 5% risk level. This result indicates that the three Chinese markets have a long-run relationship at 5% risk level.

This partially confirms graphical observation on Figures 1 where we notice a common trend between SSE, SZSE and HKSE. In addition, from a graphical point of view, the trend was

interrupted around the end of 2005 - early 2006. We can clearly identify two periods after and before this break especially for Shanghai and Shenzhen: a first period from 1993 to 2005 and a second period from 2006 to 2017. This break can affect the robustness of the co-integration test, then, we need to analyze more precisely it.

4.2 Granger causality and Cointegration on 1993- 2005 and 2006-2017 subperiods

The break observed previously, coincides with the Non-Tradable Share reform established at the end of 2005. The previous results do not consider this important change in the mainland markets organizations. So, we can suppose that the relationships can change according to this fact. To improve the analysis and include the effect of the reform, the sample is divided in two periods:

- First period from January 1, 1993 to December 30, 2005 corresponding to the pre-NTS Reform phase.
- Second period from January 2, 2006 to December 29, 2017 corresponding to the post-NTS Reform phase.

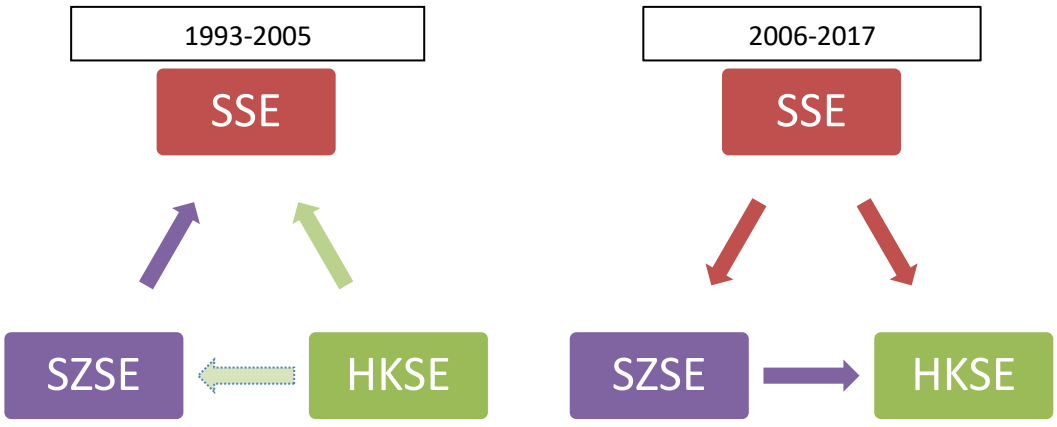
In order to confirm our hypothesis on this break, a Chow test (1960) of comparison of the regression coefficients (Table 2) between sub-periods is performed. Results confirm the presence of a structural break in the three relations.

Table 2: Chow Test Results

Variable explained	LHKSE	LSSE	LSZSE
Chow Test stat	561.25	112.68	322.21

The Unit-Root Tests are than performed on these two sub-periods and are similar to the previous one. All series are DS (I(1)) processes without drift for the two sub-periods.
We use the same methodology as previous. Figures 3 summarize results of Granger Causality Tests for the two sub-periods (see Appendix 2 for more details):

Figures 3: Granger Causality results:



SSE linkages with other markets are reversed after the reform. SSE was both influenced by SZSE and HKSE during the first period whereas it influences SZSE and HKSE after the reform. It is similar for HKSE, during the first period it influences SSE and SZSE, but after, it is influenced by others stocks markets. Similar conclusions can be made for SZSE. Compare to Figure 2, the bi-causality relationships, see for the global period, are in fact decomposed across time.

This result highlights the effects of the reform on the linkages between Chinese markets. After the reform, SSE becomes the source of causality, so we can conclude that it leads the relationships. At the opposite, Hong-Kong stocks market does not cause the continental Chinese markets because it is influenced by them.

Moreover, the co-integration tests indicate that there are no co-integration relations for the first period, but there are two cointegrations relationships for the second period (see Table 3). This shows that the cointegration overall the period is time-varying: there is a long-term relationship between the two mainland stock markets and HKSE since the NTS reform.

Table 3: Co-integration Analysis Results by Periods

3.1: First Period: 1993-2005

Hypothesized No. of CE(s)	None	At most 1	At most 2
LSSE, LSZSE and LHK			
Trace Statistic	27,15	12,38	3,45
Critical Value (0,05) -Trace	29,8	15,49	3,84

3.2: Second Period: 2006-2017

Hypothesized No. of CE(s)	None	At most 1	At most 2
LSSE, LSZSE and LHK			
Trace Statistic	33,62	15,5	2,52
Critical Value (0,05) -Trace	29,8	15,49	3,84

5. Time-Frequency Analysis of co-movements between Mainland Markets and Hong Kong

In this section, we extend the previous results by computing Wavelets Coherence and Phase Difference. To study the effect of the opening reforms on the level of correlation, we extract the time-Frequency Correlations between pairwise DLHKSE, DLSSE and DLSZSE variables and for selected frequencies. We complement the analysis by identify the leaderships of relationships through Phase and ITL across the selected frequencies.

5.1 Wavelets Coherence and Phase

To simplify interpretation, the Wavelets Coherence and Phase are graphically represented on Figures 4. The color code indicates the intensity of the coherence: when color turns red the two series strongly comove whereas when color turns blue the relationship is weaker.

The arrows illustrate the phase difference:

- arrow pointing UP-RIGHT: $x(t)$ and $y(t)$ move together in phase so they are positively correlated. and $x(t)$ leads $y(t)$.
- arrow pointing UP-LEFT $x(t)$ and $y(t)$ move together in anti-phase so they are negatively correlated and $y(t)$ leads $x(t)$.
- arrow pointing DOWN-RIGHT: $x(t)$ and $y(t)$ move together in phase so they are positively correlated. In this case, $y(t)$ leads $x(t)$.
- arrow pointing DOWN-LEFT: $x(t)$ and $y(t)$ move together in anti-phase so they are negatively correlated and $x(t)$ leads $y(t)$.

The time is on the x-axis while frequencies are on y-axis. The frequencies are expressed in Period (in days): High Frequencies represent short-run investment horizon (at the top of y-axis) while Low-Frequencies illustrate long-run horizons (at the bottom of y-axis).

Figures 4: Wavelets Coherence and Phase between Chinese markets

Figure 4-1: HKSE – SSE

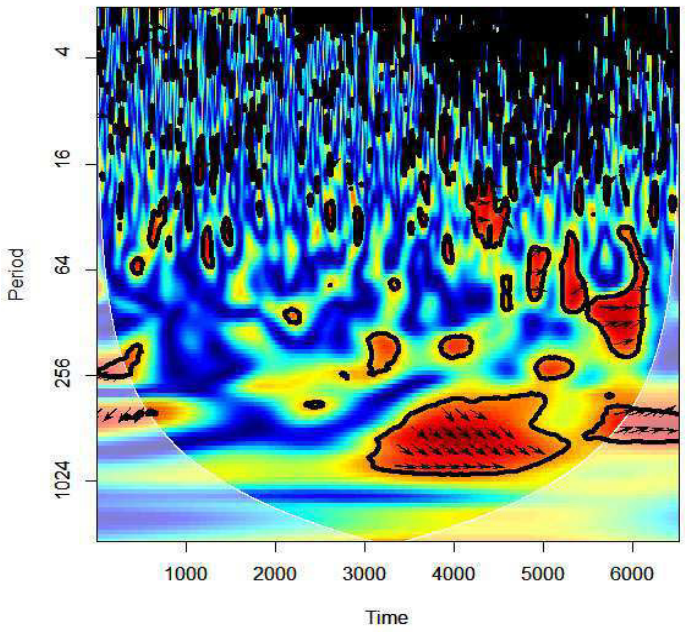


Figure Fig 4-2 HKSE-SZSE

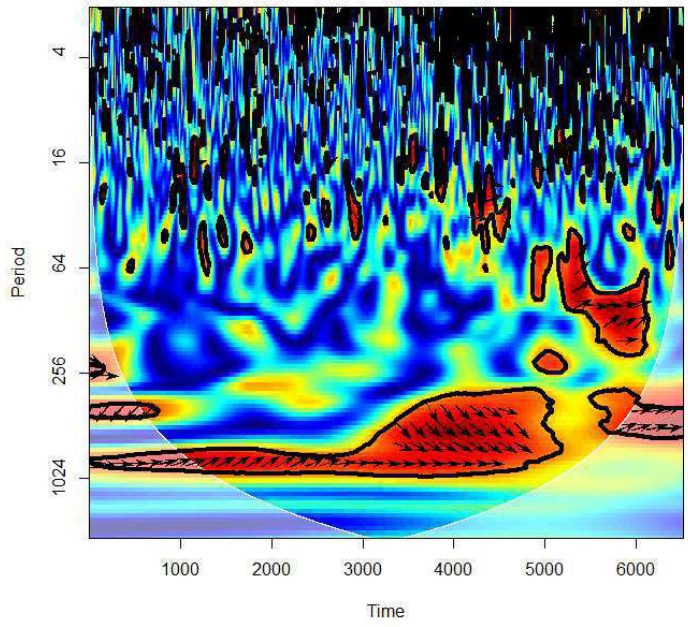
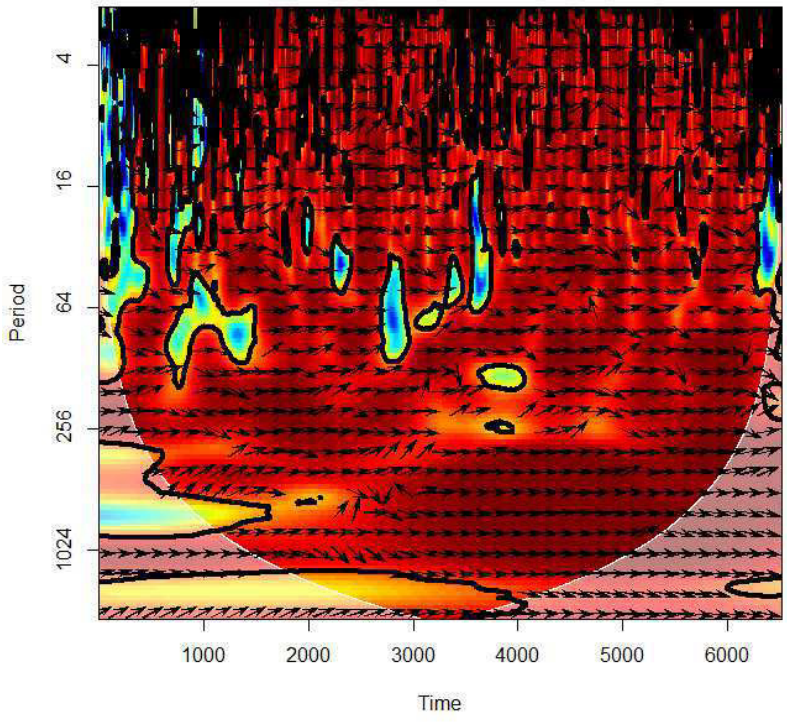


Figure 4-3: SZSE-SSE



We observe the coherences between Hong Kong-Shanghai and Hong Kong-Shenzhen are relatively similar and mainly dominated by blue. However, we notice zones of strong co-movement located at low-frequencies around period 1024 days (or 4 years) starting the time index 3000 (mid 2004). For the HKSE-SSE relationship the co-movement at the Period 1024 was relatively medium compare to HKSE-SZSE btu started to increase from 2500-time index (mid 2002). At frequency 256 (1 years) we also remark for HKSE-SSE strong co-movements in 2005-2006 (from 3000 to 3500 on x-axis) and during 2008 financial crisis (around 4000 on x-axis). On medium frequencies, we observe an archipelago of strong co-movements zones from mid-2009 to 2014 (from 4500 time index to 6000 on x-axis). At high-frequencies, the black color indicates that there is an alternance of low and strong co-movement highlighting that the relationship is highly erratic across time. The relationship between Shenzhen and Shanghai is dominated by red indicating that the two markets strongly move together whatever frequencies and time. These results indicate that the two mainland markets are highly correlated each other but their relationship with Hong Kong appear stronger after the reform.

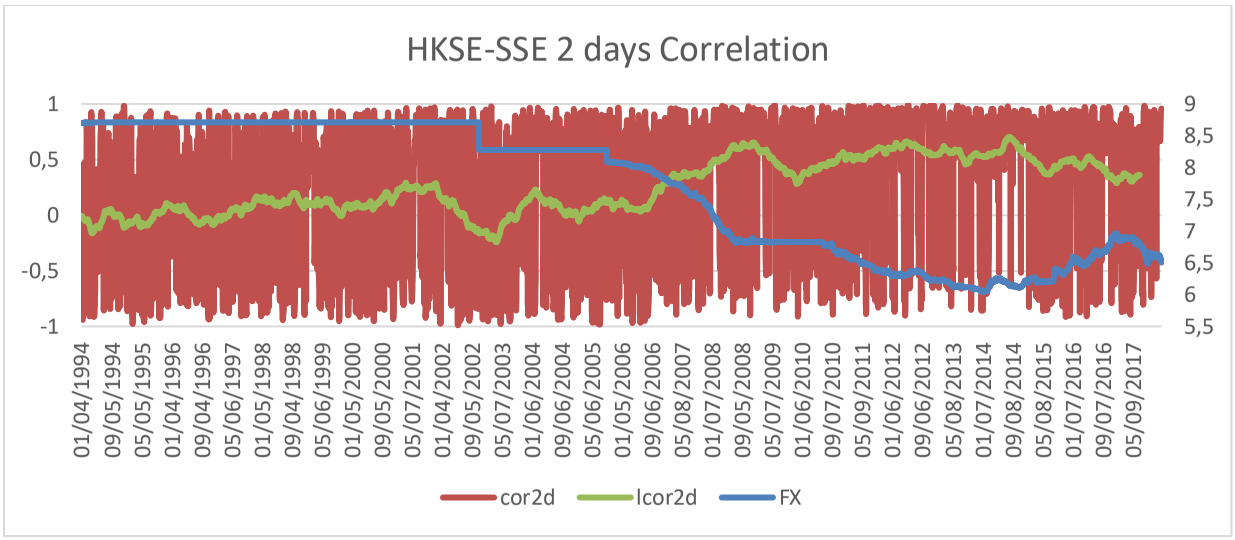
Concerning the Phase difference represented by arrows, we note that in long-run (at low-frequencies) SSE leads HKSE but HKSE lead SSE at medium frequency. For HKSE-SZSE relationships, we note that HKSE leads before 2002/2003 (2500/3000 on x-axis) but after this period SZSE leads.

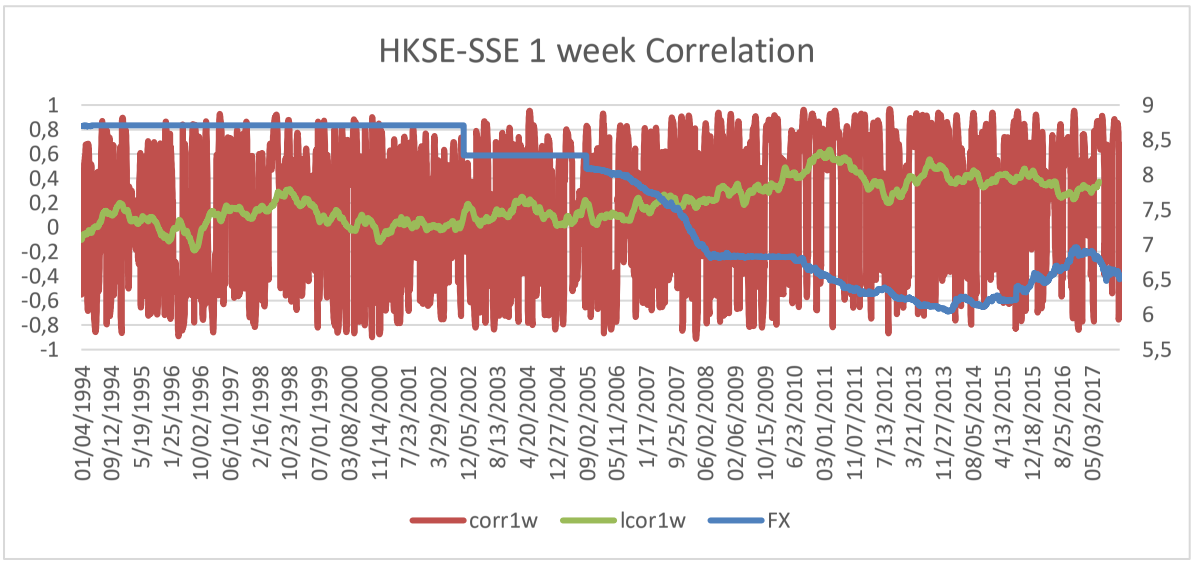
Wavelets coherence and phase provide a useful result but we need to extract time-frequency correlation and ITL to better study the sign of the relationship and identify the leadership. Because of the numerous results, we select specific frequencies to analyze the correlation coefficients across time. We consider the following frequencies: 2 days, 1 week, 1 quarter, 1 years and 4 years. However, the correlation coefficients at high-frequencies are highly erratic and volatile, so we smooth these series to ease the reading. Smoothed series are named lcor.

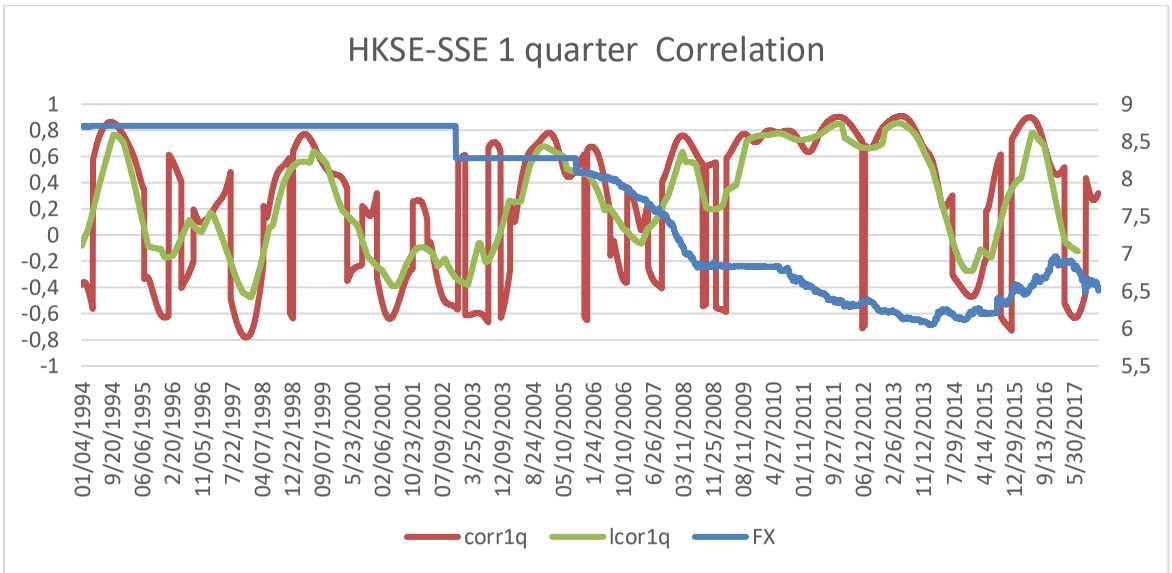
In order to analyze the effect of the reforms on Chinese markets correlations for the selected frequencies, we consider the Yuan/USD exchange rates (FX) as a proxy variable of opening up.

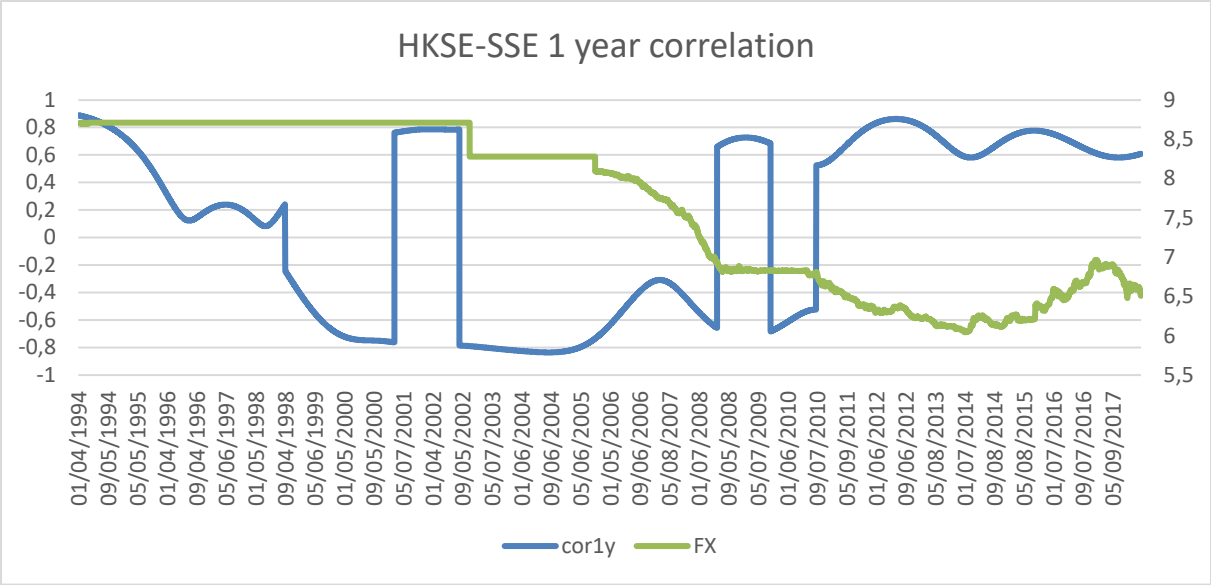
Figures 5 illustrate the time-frequency correlations between Hong Kong and Shanghai, and also the Yuan/USD exchange rate. Figures for HKSE-SZSE are in appendixes 3. Concerning the SZSE-SSE linkages, results are not presented as the correlations are very high across time and for all selected frequencies. However, we note a low correlation area at frequency 1 quarter from 2003 to 2004.

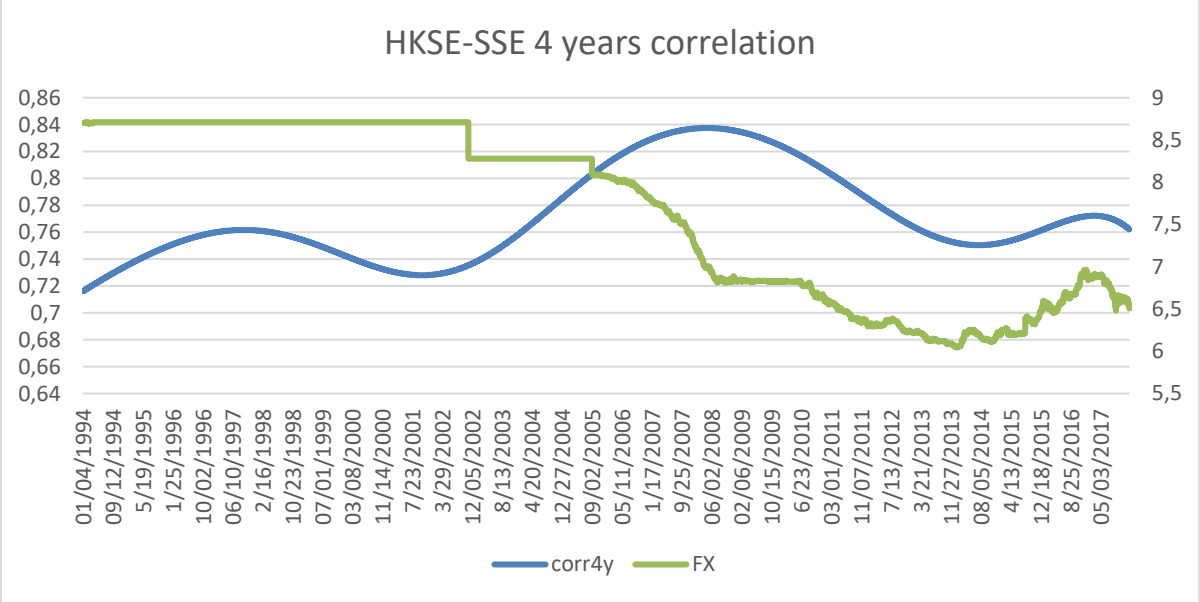
Figures 5: Time-Frequency Correlations between Hong Kong and Shanghai











These graphics confirm the previous observations from Figures 4. The correlations between mainland market and Hong Kong are highly volatile at high-frequencies (2 days, 1 week and 1 quarter in lesser extent). However, the smoothed series (lcor) show that average correlations are relatively small oscillating around 0 but increase stared 2005-2006 to an average value of 0.5 at 2 days frequency and around 0.3 - 0.4 at 1 week frequency.

Correlation at 1 year reveals those linkages between SSE -HKSE and SZSE-HKSE are negative from 1998 to 2008 but positive during 2001 – 2002 and the 2008-2007 crisis. However, after the crisis the correlation is highly positive with a coefficient between [0.6; 0.8], except during 2010 for which coefficients are negative.

Long run Correlation at 4 years indicates SSE and HKSE are strongly correlated with a coefficient varying between 0.7 and 0.85. We note that starting 2001 the correlation increases and reach a peak during the 2008 crisis. After the crisis, the correlation is stable around 0.75. Results for HKSE-SZSE relationship are similar but coefficient correlations are greater at the

beginning. We can suppose that this fact is due to the proximity of Shenzhen with Hong Kong and the fact that it was the first SEZ. We note also a local peak in the correlations around 1997-1998 corresponding to the period of Hong Kong Retrocession.

To better confirms the effect of the opening reforms on correlations between markets, we construct a dummy variable, IND, equal to 0 before 2005 and 1 after. We also consider the Yuan/USD exchange rate (FX) as a proxy variable representing the Opening reform. The exchange rate was strongly monitored and pegged against the USD before its internationalization and gradually turn into a managed floating regime. Consequently, the drop of FX observed since 2002 and 2006 are related to a gradual relaxation of exchange control as a part of a greater opening reforms. For the selected frequency, we regress the correlation on IND and on FX, as follow:

$$\rho_t = constant + \beta\, IND_t + \varepsilon_t$$

$$\rho_t = constant + \beta\, FX_t + \varepsilon_t$$

We estimate these models by OLS for HKSE-SSE and HKSE-SZSE correlations. Results are presented in Tables 4.

Tables 4: opening effect on markets correlation

Table 4.1
HKSE-SSE

	cor2d	lcor2d	cor1w	lcor1w	cor1q	lcor1q	cor1y	cor4y
constant	1.905***	1.885***	1.329 ***	1.349 ***	1.506 ***	1.580 ***	2.253 ***	0.877 ***
FX	-0.215***	-0.212 ***	-0.146 ***	-0.145 ***	-0.163 ***	-0.171 ***	-0.277 ***	-0.014 ***
R^2	0.105 ***	0.803 ***	0.065 ***	0.737 ***	0.096 ***	0.215 ***	0.190 ***	0.170 ***
constant	0.058***	0.060 ***	0.08***	0.079***	0.121***	0.060***	-0.131***	0.756 ***
IND	0.441***	0.434***	0.289***	0.279***	0.304***	0.332***	0.56***	0.034 ***
R^2	0.1077***	0.814***	0.062***	0.664 ***	0.081***	0.17***	0.189 ***	0.247 ***

Table 4.2
HKSE-SZSE

	cor2d	lcor2d	cor1w	lcor1w	cor1q	lcor1q	cor1y	cor4y
constant	1.671***	1.700***	1.245 ***	1.213 ***	1.365 ***	1.494***	1.969 ***	0.565 ***
FX	-0.185***	-0.189***	-0.135***	-0.131 ***	-0.152 ***	-0.167***	-0.238***	0.033***
R^2	0.079 ***	0.744 ***	0.056 ***	0.664 ***	0.0752 ***	0.178 ***	0.164 ***	0.516 ***
constant	0.077***	0.075***	0.090 ***	0.092***	0.062 ***	0.060***	-0.077 ***	0.843 ***
IND	0.39 ***	0.398 ***	0.260***	0.249***	0.299 ***	0.332***	0.477 ***	-0.057
R^2	0.086 ***	0.799***	0.051 ***	0.578 ***	0.07 ***	0.17***	0.159 ***	0.376 ***

Note: Null hypothesis is not accepted at the ***1%, **5% and *10% risk level

The parameters are significant for all estimations. Parameter for FX are negative indicating that the fall of the exchange rate, representing a greater opening up, increases the correlation between mainland markets and Hong Kong market. However, this effect is lesser on HKSE-SSE correlations at 4 years and positive for HKSE-SZSE correlations. The estimations with dummy variable, IND, provides similar results. The parameters are positive and significant indicating that correlations increase after the reform period except for HKSE – SZSE correlation at 4 years where the parameter is negative.

The R^2 also are significant but relatively low as their stand between [0.05; 0.17] for models with non-smoothed correlations. This result is coherent because opening reforms are not the unique factor affecting correlations and linkages between markets. If we the smoothed correlations, we find similar parameters values but the R^2 are significantly greater. Then we can assume that short-run correlations between mainland and Hong Kong tend to strengthen with opening while being highly volatile and subjected to shocks.

In Table 5, we apply the estimated parameters with the dummy variable, IND, to compute an estimated coefficients correlation $\hat{\rho}$. Before 2005, the correlation is equal to the constant while after 2006 correlation equals to $constant + \beta$. Similar results are observed considering the average value of exchange rate after and before the break.

Table 5: Estimated Correlation Coefficients by dummy variable

HKSE-SSE	1994-2005	2006-2017
$\hat{\rho}$ 2 days	0.06	0.5
$\hat{\rho}$ 1 week	0.08	0.37
$\hat{\rho}$ 1 quarter	0.121	0.425
$\hat{\rho}$ 1 year	-0.131	0.429
$\hat{\rho}$ 4 years	0.756	0.79
HKSE-SZSE	1994-2006	2006-2017
$\hat{\rho}$ 2 days	0.077	0.467
$\hat{\rho}$ 1 week	0.09	0.35
$\hat{\rho}$ 1 quarter	0.062	0.361
$\hat{\rho}$ 1 year	-0.077	0.4
$\hat{\rho}$ 4 years	0.843	0.786
IND	0	1

We see that the correlation coefficients strongly increase in 2006-2017 at frequencies 2 days, 1 week and 1 quarter but at an intermediary level. At 1 year frequencies results confirmed the previous observations made on figures 5: before the 2006 the correlation was negative and positive after. At long-run (4 years), the effect of the opening reforms appears to be lesser (correlation increases a little) but it was already at high level.

The combination of Wavelets Coherence, time-frequency correlations and the regression with dummy and FX variable provide similar results in nature concerning the impact of the series of reforms. We can assume that the opening reforms significantly increased the correlation between markets at short-run as the level was relatively low at the beginning. However, at

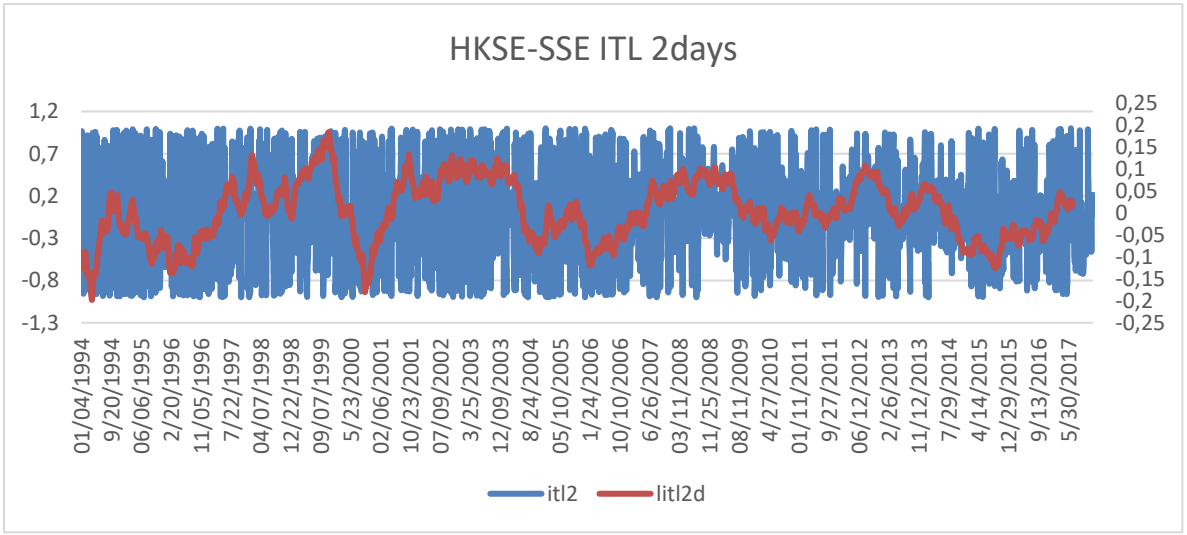
long-run, the reforms change the sign of the correlation at 1 years but have a few impacts at 4 years as correlation was high and markets already interdependent. However, we need to study the Phase Difference and Instantaneous Time Lag to complement these results by identify the leadership and influence relationships.

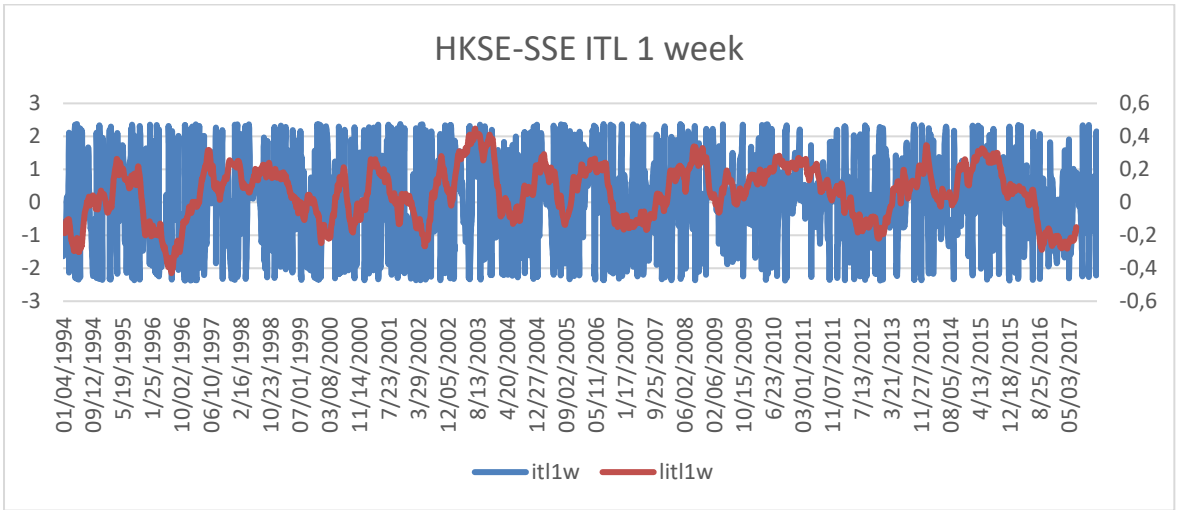
5.2 ITL and Leadership analysis

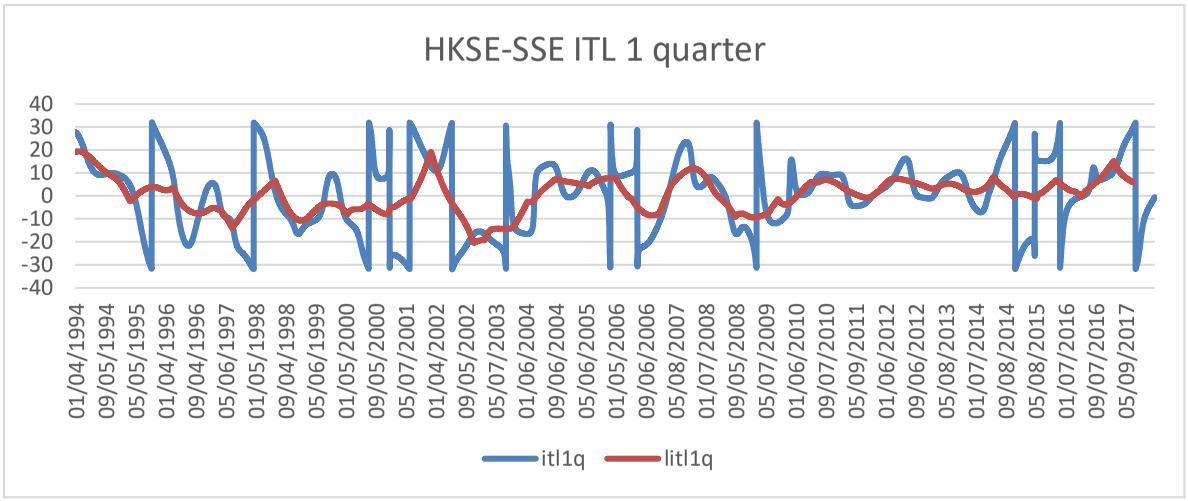
The Phase Difference are transcribed into ITL to ease interpretation of lead-lag relationship between mainland and Hong Kong markets. At short-run, the influences of markets on another are equal to 1 lagged day at most for frequencies 2 days, and at most 2-3 lagged days at frequency 1 week. As example, Hong Kong leads Shanghai with 1 lag at short-run (at frequency 2 days) and with 2 lagged days at frequency 1week.

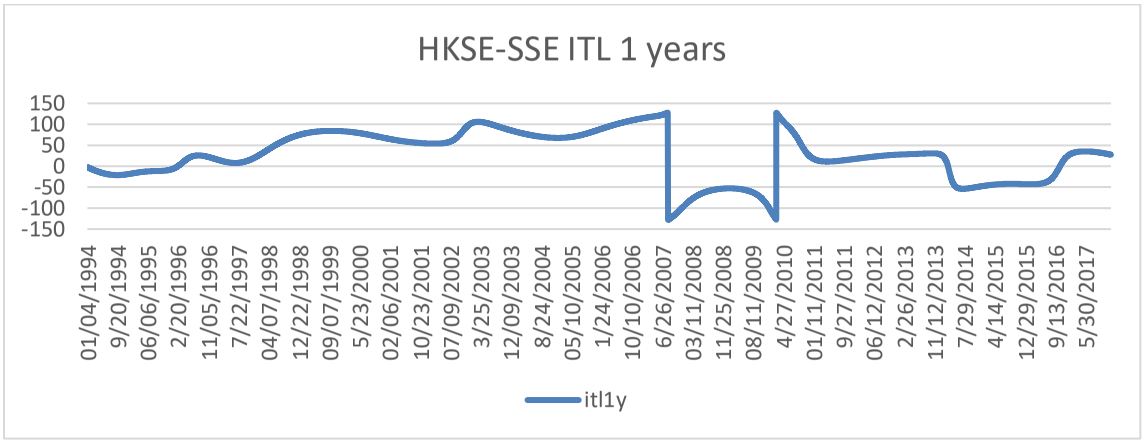
We conserve the same frequencies, and the results at high-frequency are smoothed to ease reading (variables called litl). Figures 6 illustrates ITL for HKSE-SSE relationship while results for HKSE-SZSE and SZSE-SSE are recorded in Appendixes A3.2 and A3.3.

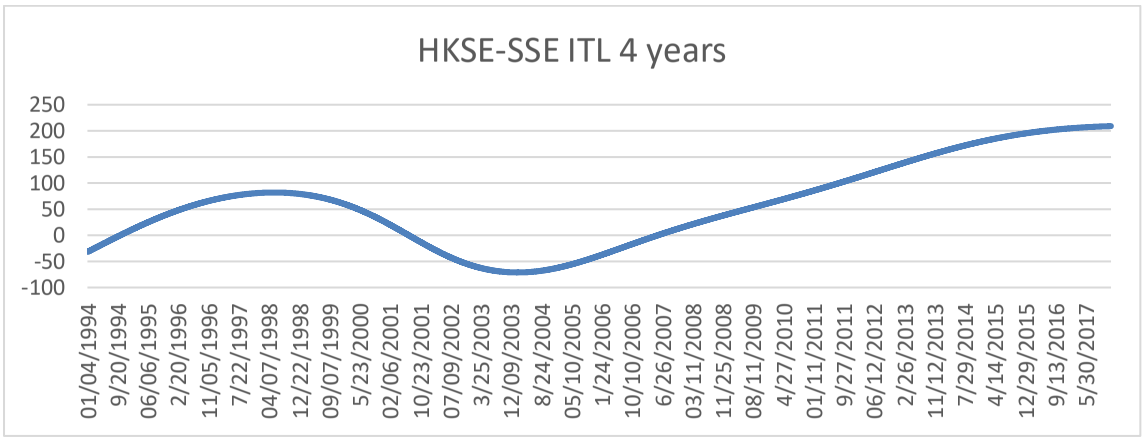
Figures 6 : ITL between Hong Kong and Shanghai











At short-run, the ITL values (at 2 days, 1 week and 1 quarter frequencies) are highly volatile, indicating that mainland markets and Hong Kong influences each other. Then, it is relatively difficult to determine a "leader" as mutual influences are observed between markets. This result is consistent with the frequency selected and it is closed to previous observed time-frequency correlations. At short-run, the relationships between markets are dependent to multiple economics factors and exogeneous shocks (crisis, news from foreign markets, internal news, etc …) and not only explaining by the opening process. Then, Results are erratic and the level and degree of correlation and co-movement strongly fluctuate.

The smoothed ITL provide an average indicator of leadership over time. We note that, in average, Hong Kong leads Shanghai from 1997 to 2004 (during Asian crisis and 2000 crisis) but from 2005 to 2007 Shanghai leads Hong Kong. During the 2007-2008 financial Crisis Hong Kong leads globally the relationship but lead-lag are small varying around 0.5 day. This result indicates a potential contagion effect from Hong Kong to Mainland Market and correspond also to an increase of average correlation. The influence of Mainland Markets on Hong Kong stared to increase in average since 2010 and became more significant in 2015-2016-2017. We can suppose that this result come from the Shanghai- Hong Kong Stock Connect Program which improve the linkage between the two markets by allowing cross-listing of mainland firm in Hong Kong. We note similar results for frequency 1 week and 1 quarter and also for the relationship Hong Kong -Shenzhen. Concerning the relationship between Shenzhen and Shanghai, the ITL values also highlight mutual influences. Smoothed correlations indicate that Shenzhen leads in average from 1994 to 1999 and from 2000 to 2007/2008 at frequency 1 week while after the crisis, Shanghai affects more and more Shenzhen and tends to drive the relationship.

At long-run (frequencies 1 year and 4 years) the results for HKSE-SSE and HKSE-SZSE are highly similar. At 1 year, we note that Mainland Markets Leads Hong Kong from 1994 to 1996 (when correlation was high but on downward trend) but Hong Kong leads Mainland Markets during Asian Crisis and until mid-1999 (when correlation was small and positive) both predate other with at most 1-month lag (20-25 days). In addition, from mid-1999 to 2000 (when correlation was high but negative) Mainland Markets have the leadership with at most 4 months lag (80-85 days) but Hong Kong leads from 2001 to mid-2002 (when correlation was high and positive) with at most 2 months lag (50 days). We note that mainland markets lead during reforms period and just after the financial crisis from 2002 to mid-2007 (when correlation was negative) with a time-lag between 3 months and 6 months. During the financial crisis, Hong Kong leads during the global collapse of indices but Mainland Markets leads from mid-2008 to mid-2009 and correlation was positive during the recovery times and time-lags are low around 1 month. To conclude, Hong Kong leads from mid-2010 to mid-2013/2014 and from end-2016 until end (around 1 month lag) while Mainland Markets leads from 2014 to end -2016 (around 2-3 months lag).

At frequency 4 years, interpretations ITL are closed to the previous one. Hong Kong leads from 1995 to mid-2001 and from mid-2007 to the end while Mainland Markets leads from mid-2001 to mid-2007 when correlation is on upward trend. We assume that Hong Kong globally influences Mainland Market while opening reforms contributed to strengthen financial market relationships. We notice that long-run linkages between Shanghai and Shenzhen are mainly dominated by Shanghai. The ITL values are relatively small indicating tight linkages.

6. Conclusion

The main objective of this article is to analyze the effect of Opening up reforms on the relationships between Mainland Markets (Shanghai and Shenzhen) and Hong Kong. Using traditional econometrics approaches, we find bi-causality linkages between SSE-SZSE, and SSE-HKSE, and a slight long-run co-relationship. However, to better appreciate changing related to reforms period, we divide in two our sample considering the NTS reform at the end of 2005 as break. Results indicate that the feed-back relationships are time varying: on the first period, HKSE and SZSE mutually Granger cause SSE, but on the second period, SSE influences both SZSE and HKSE. Furthermore, after the reform, the two mainland stock markets establish a long-term relationship with HKSE.

To extend the analysis, we employ a time-frequency approach, the Wavelets, useful to model the relationship across time and according frequencies (related to investment horizon and cycles). The wavelets Coherence and Phase Difference are used to compute the time-frequency correlations coefficient and Instantaneous time-lag (ITL). By the way, we can determine the intensity of correlation between markets and the leadership at each time and for selected frequencies (2 days, 1 week, 1 quarter, 1 year and 4 years).

The correlation between Mainland markets and Hong Kong are highly erratic and volatile at short-run. However, the correlation tends to increase during the reforms period and become greater after 2005-2006, as in average the estimated value of correlation passe from [0.05 ; 0.10] to [0.30 ; 0.50]. We note there are mutual influences at short-run between Hong Kong and Mainland Markets both before and after opening. However, linkages are globally dominated by Hong Kong before reforms and during crisis periods. Mainland Markets lead Hong Kong when opening reforms are announced and established and become significantly important after 2010-2011 corresponding to the beginnings of Yuan Internationalization through Hong Kong.

In long-run, the Liberalization and Modernization processes of Chinese economy at the beginnings of the 1990s reinforced the linkages with the newly created mainland markets and Hong Kong. However, the State control on capital flow exerted pressure and tend to decrease the degree of correlation. The Asian Crisis coincides with a low correlation and a Hong Kong leaderships. Mainland markets was relatively closed and less affected by crisis resulting in a negative correlation after the crisis. However, China shown sign of openness by joining WTO, so correlation became highly positive while being dominated by Hong Kong. However, correlation becomes negative again during the reforms period may be due and multiple attempts/failures and the resulting adjustments. In 2007, Chinese markets started to explode and tend to be greater affected by external shock as Hong Kong Leadership in 2008 let's suppose. After the 2008 Crisis, correlation is stable and relatively high and the Hong Kong leadership until 2014 indicate a possible effect of the Yuan internationalization while Shanghai leadership from 2014 assumes a potential effect of the Hong Kong Stock Connect Program. However, the Shenzhen Stock Connect Program marks the beginnings of Hong Kong Leadership on the Shenzhen market.

Both results of standards econometrics tools and wavelets approaches are coherent on the effect of the reforms period. However, the time-frequency framework provides more details on the double dynamics of the correlation and also on the influence's relationship between the markets. Some results are then confirmed such as the increasing power of Shanghai while others are nuanced as Hong Kong still stay a major influencer of mainland market. These results are coherent with the literature review indicating that opening reforms tend to increase correlations between mainland markets and Hong Kong. The time-frequency framework highlights that the relationships between markets are multidimensional with complex interactions and influences according to horizon considered.

To conclude, we repeat that the opening process of Chinese market is still ongoing entering in an acceleration phase since 2018-2021. The recent advances like new Securities Law, the new economic of "Dual Circulation» allow a greater access to mainland market to foreign investors in various sectors with a key role of Hong Kong as a "hub" for foreign and Chinese investors.

As our results suggest for the reform period, these new phase advancements will probably increase the degree of integration between Shanghai, Shenzhen and Hong Kong. In this case, policymakers or investors should select a frequency of interest and an investment horizon to better appreciate relationships between Mainland and Hong Kong market.

Appendixes

Appendix Table A1: Unit Root Test Results

1993-2017	ADF-INTERCEPT AND TREND	ADF-INTERCEPT	PP-INTERCEPT AND TREND	PP-INTERCEPT
LHKSE	-3,769(0)*	-2,256(0)***	-3,787(4)*	-2,264(3)***
LSSE	-2,794(6)***	-1,556(6)***	-2,782(7)***	-1,735(5)***
LSZSE	-2,008(0)***	-1,124(0)***	-2,205(13)***	-1,223(12)***
DLHKSE	-80,47(0)	-80,473(0)	-80,470(4)	-80,473(4)
DLSSE	-32,874(5)	-32,877(5)	-81,425(3)	-81,431(3)
DLSZSE	-36,788(3)	-36,791(3)	-78,813(10)	-78,818(10)

Notes: Values in the parentheses are the Lag Length (ADF) or the Bandwidth (PP) used in the estimation of the unit root test. *denote accept null hypothesis at the 1% critical value, ** 5% critical value, ***10% critical value.

Appendix 2: Granger Causality Test Results

A2.1: First Period from 1993 to 2017

1993-2017	Null Hypothesis	
Lags	DLSSE does not Granger Cause DLHKSE	DLHKSE does not Granger Cause DLSSE
1	16,66***	4,94**
2	8,43***	3,80**
3	5,65***	3,49**
4	4,15***	3,92***
5	3,48***	3,96***
	DLSZSE does not Granger Cause DLHKSE	DLHKSE does not Granger Cause DLSZSE
1	16,32***	2,61
2	8,259***	1,69
3	5,51***	1,69
4	4,08***	2,16*
5	3,27***	2,67**
	DLSZSE does not Granger Cause DLSSE	DLSSE does not Granger Cause DLSZSE
1	28,89***	8,85***
2	14,52***	4,57**
3	9,87***	3,13**
4	7,60***	3,59***
5	6,19***	3,97***

Note: Null hypothesis is not accepted at the ***1%, **5% and *10% critical value.

A2.2: First Period from 1993 to 2005

1993-2005	Null Hypothesis	
Lags	DLSSE does not Granger Cause DLHK	DLHK does not Granger Cause DLSSE
1	2,71066*	1,78423
2	1,57557	1,94506
3	1,14622	2,8999**
4	0,9076	2,6359**
5	0,78047	3,17236***
	DLSZSE does not Granger Cause DLHK	DLHK does not Granger Cause DLSZSE
1	2,99101*	1,20482
2	1,83088	0,66565
3	1,31418	1,89888
4	1,19704	1,95909*
5	0,96634	3,09744***
	DLSZSE does not Granger Cause DLSSE	DLSSE does not Granger Cause DLSZSE
1	20,4229***	4,50260**
2	10,2155***	2,4244*
3	6,6766***	1,6992
4	5,12789***	1,61107
5	4,72686***	1,62736

Note: Null hypothesis is not accepted at the ***1%, **5% and *10% critical value.

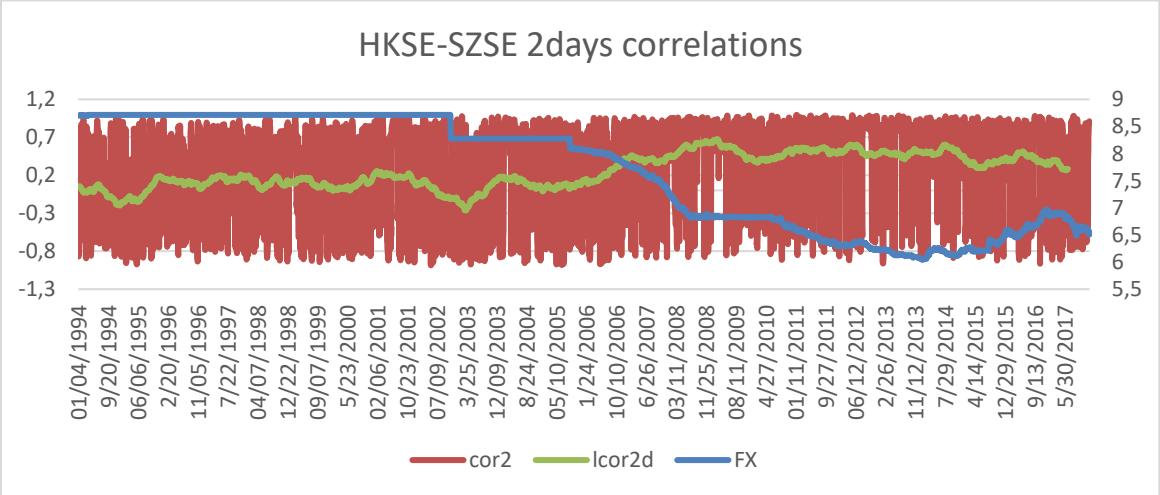
A2.3: Second Period from 2006 to 2017

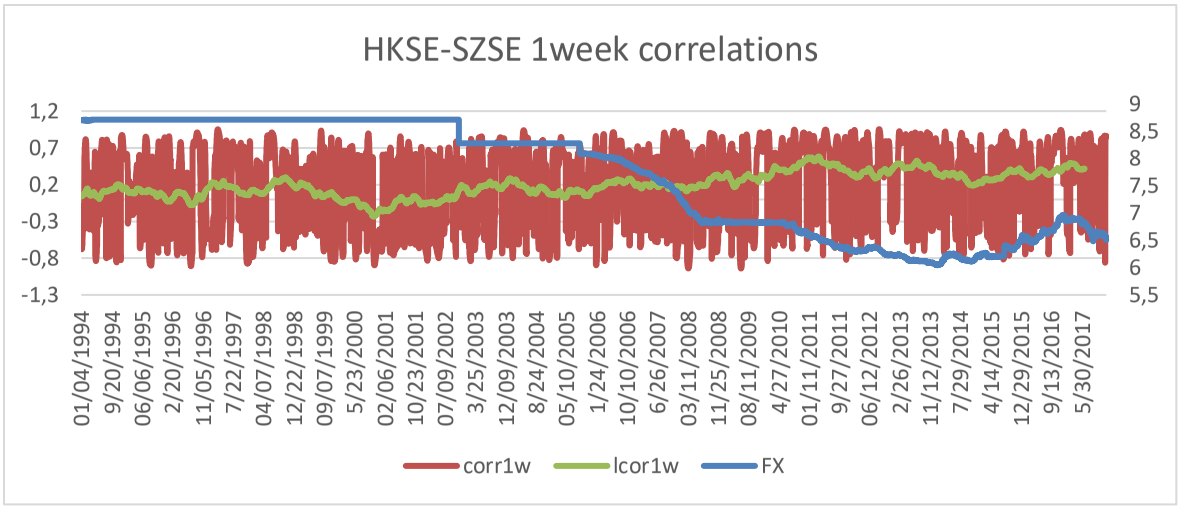
2006-2017	Null Hypothesis	
Lags	DLSSE does not Granger Cause DLHK	DLHK does not Granger Cause DLSSE
1	20,6503***	2,47728
2	10,4601***	1,08884
3	8,01568***	0,72851
4	6,007***	1,13196
5	5,11573***	0,95634
	DLSZSE does not Granger Cause DLHK	DLHK does not Granger Cause DLSZSE
1	14,5989***	0,83947
2	7,42745***	0,54646
3	6,12369***	0,33832
4	4,79332***	0,59645
5	3,89163***	0,44992
	DLSZSE does not Granger Cause DLSSE	DLSSE does not Granger Cause DLSZSE
1	3,18683*	5,93907**
2	1,72101	3,52179**
3	2,46539*	3,06367**
4	2,22016*	4,69871***
5	2,30647**	4,84741***

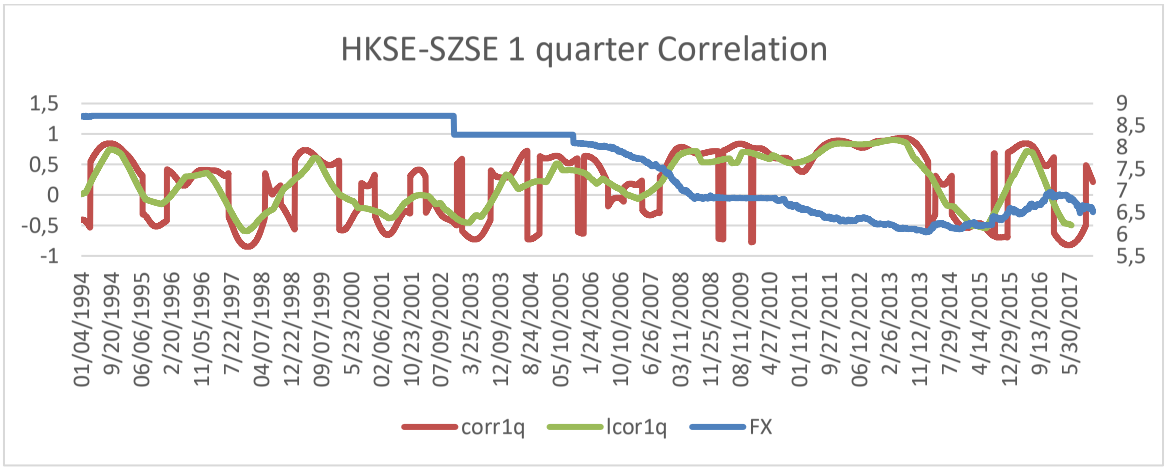
Note: Null hypothesis is not accepted at the ***1%, **5% and *10% critical value

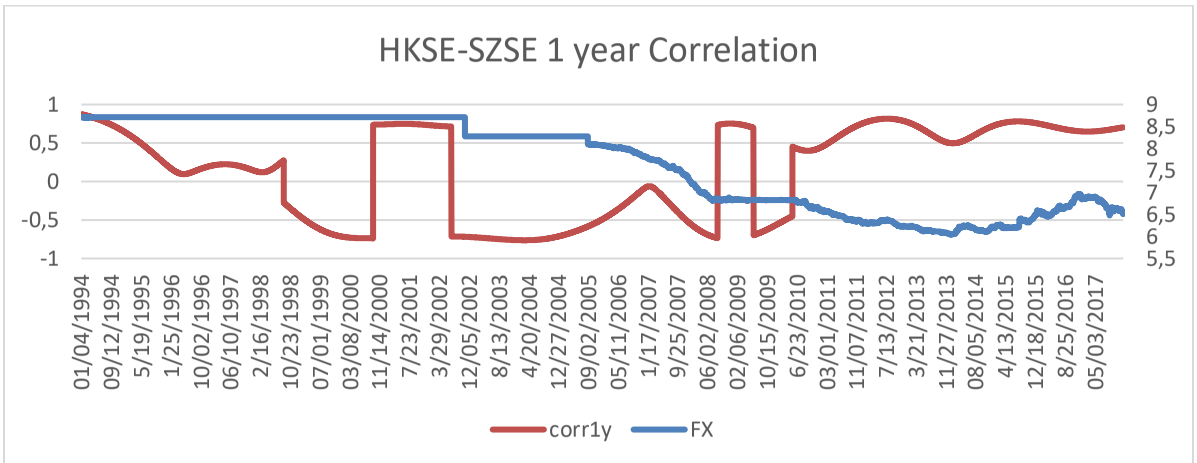
Appendix 3: Time-Frequency Correlations and ITL between Hong Kong and Shenzhen

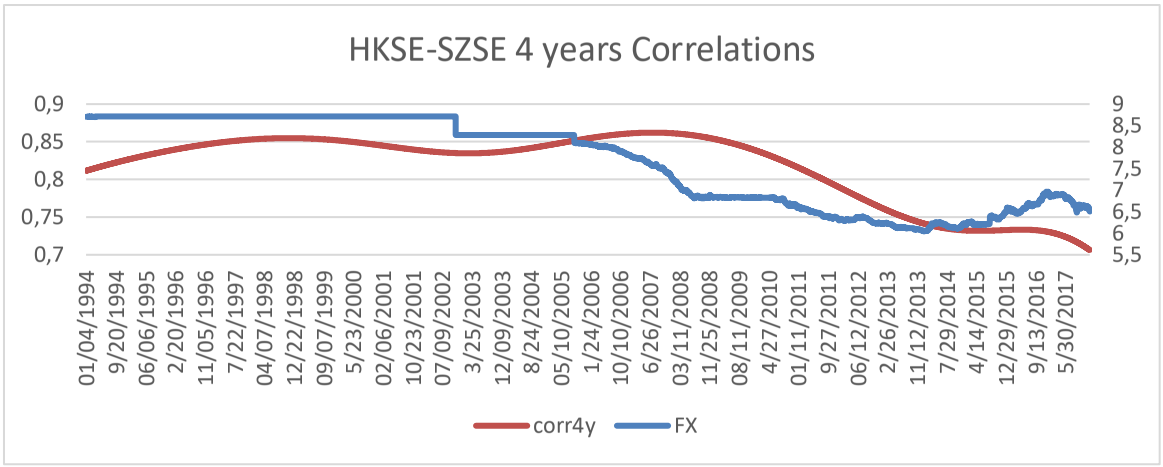
A3.1 Time -Frequency Correlaitons



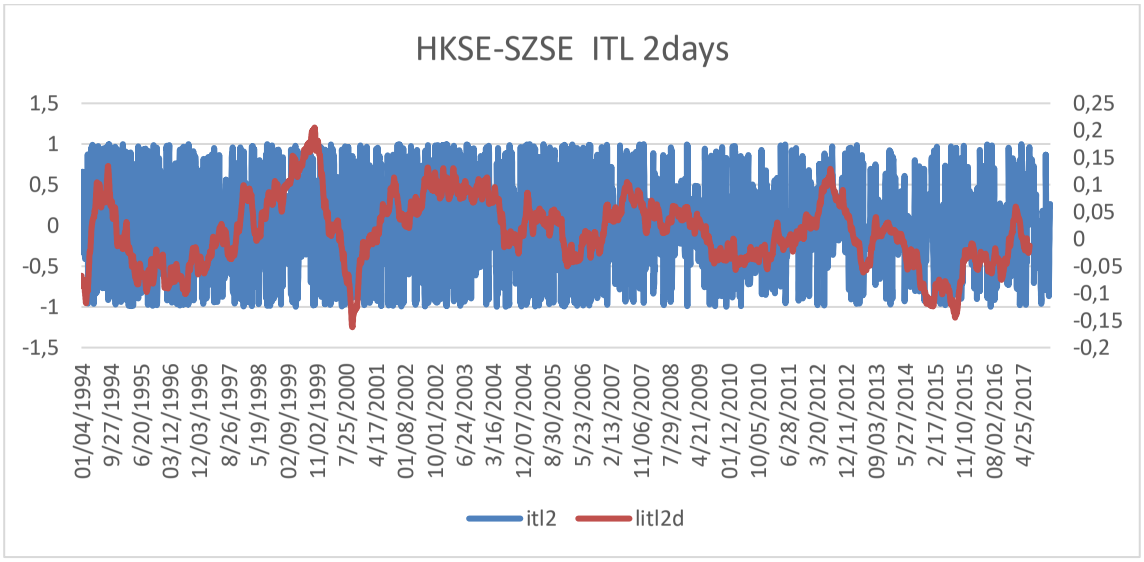

HKSE-SZSE 1week correlations
1,2
0,7
0,2
-0,3
-0,8
-1,3
9
8,5
8
7,5
7
6,5
6
5,5
01/04/1994
9/20/1994
06/06/1995
2/20/1996
11/05/1996
7/22/1997
04/07/1998
12/22/1998
09/07/1999
5/23/2000
02/06/2001
10/23/2001
07/09/2002
3/25/2003
12/09/2003
8/24/2004
05/10/2005
1/24/2006
10/10/2006
6/26/2007
03/11/2008
11/25/2008
08/11/2009
4/27/2010
01/11/2011
9/27/2011
06/12/2012
2/26/2013
11/12/2013
7/29/2014
4/14/2015
12/29/2015
9/13/2016
5/30/2017
corr1w
lcor1w
FX

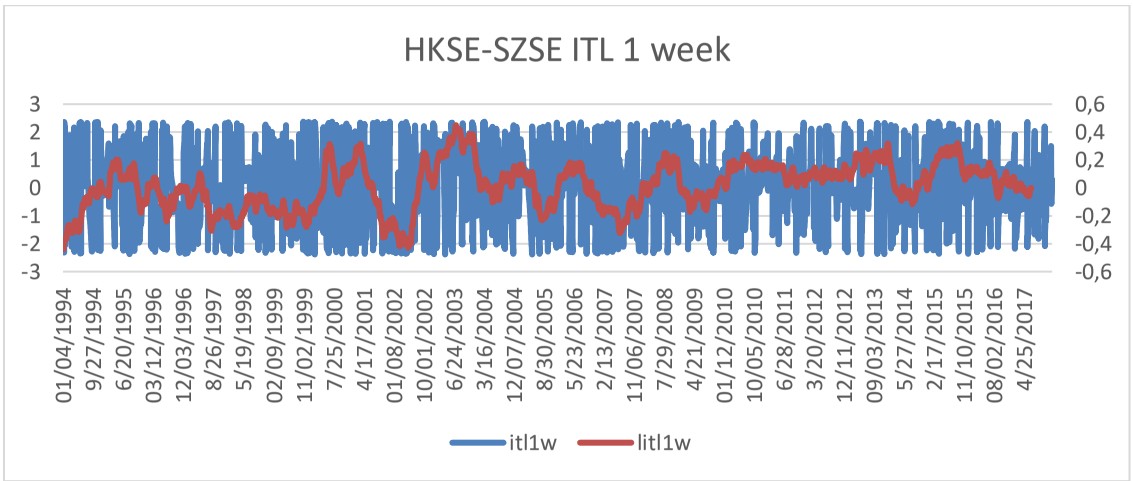

HKSE-SZSE 1 quarter Correlation
1,5
1
0,5
0
-0,5
-1
9
8,5
8
7,5
7
6,5
6
5,5
01/04/1994
9/20/1994
06/06/1995
2/20/1996
11/05/1996
7/22/1997
04/07/1998
12/22/1998
09/07/1999
5/23/2000
02/06/2001
10/23/2001
07/09/2002
3/25/2003
12/09/2003
8/24/2004
05/10/2005
1/24/2006
10/10/2006
6/26/2007
03/11/2008
11/25/2008
08/11/2009
4/27/2010
01/11/2011
9/27/2011
06/12/2012
2/26/2013
11/12/2013
7/29/2014
4/14/2015
12/29/2015
9/13/2016
5/30/2017
corr1q
lcor1q
FX

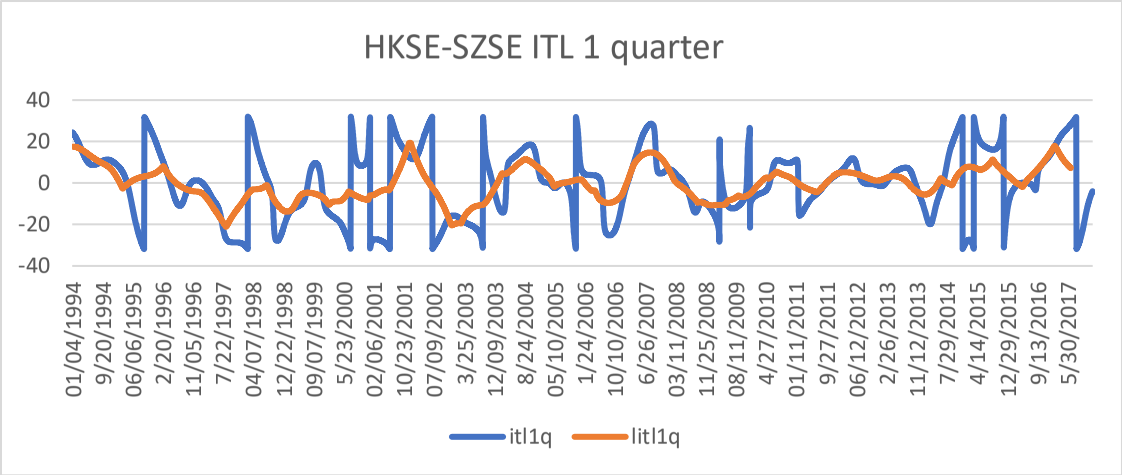

HKSE-SZSE 1 year Correlation
1
0,5
0
-0,5
-1
9
8,5
8
7,5
7
6,5
6
5,5
01/04/1994
09/12/1994
5/19/1995
1/25/1996
10/02/1996
06/10/1997
2/16/1998
10/23/1998
07/01/1999
03/08/2000
11/14/2000
7/23/2001
3/29/2002
12/05/2002
8/13/2003
4/20/2004
12/27/2004
09/02/2005
05/11/2006
1/17/2007
9/25/2007
06/02/2008
02/06/2009
10/15/2009
6/23/2010
03/01/2011
11/07/2011
7/13/2012
3/21/2013
11/27/2013
08/05/2014
4/13/2015
12/18/2015
8/25/2016
05/03/2017
corr1y
FX

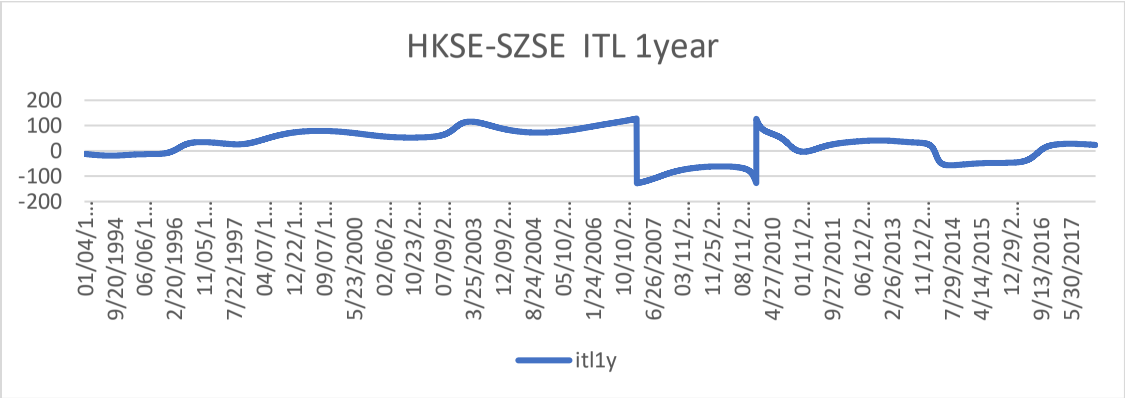


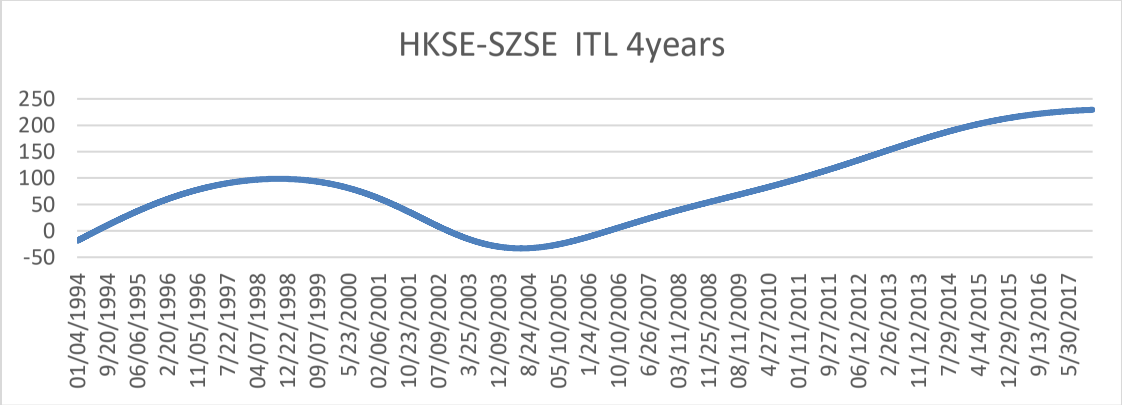
A3.2 ITL for HKSE-SZSE relationship



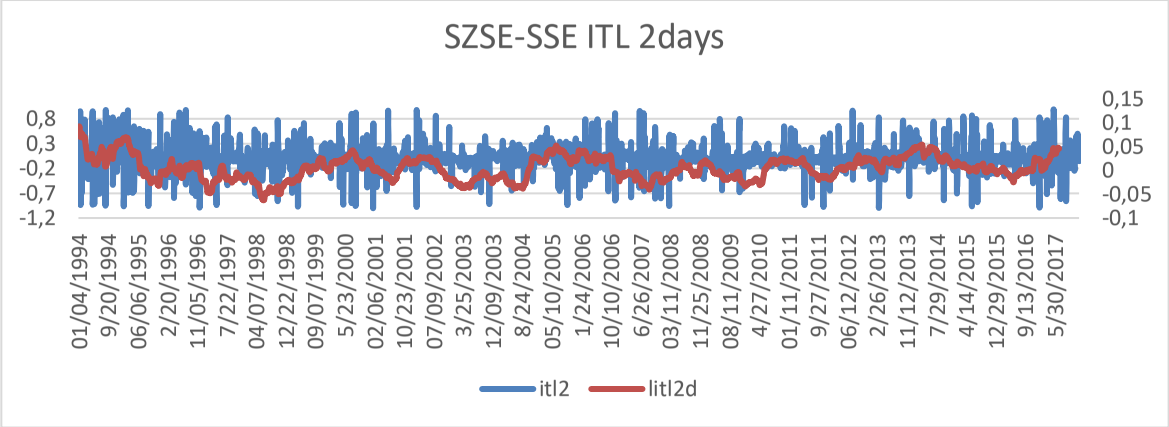


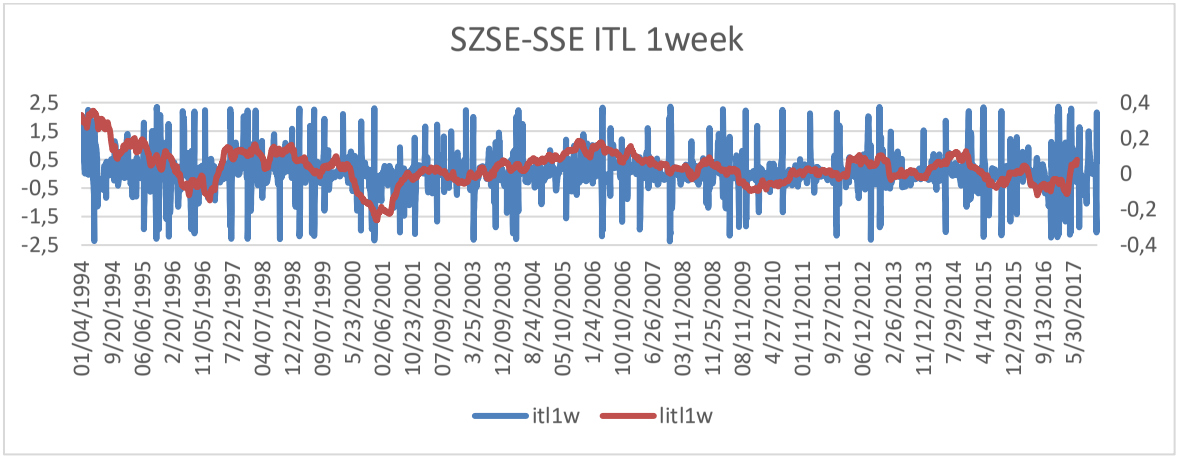

HKSE-SZSE ITL 1 quarter
40
20
0
-20
-40
01/04/1994
9/20/1994
06/06/1995
2/20/1996
11/05/1996
7/22/1997
04/07/1998
12/22/1998
09/07/1999
5/23/2000
02/06/2001
10/23/2001
07/09/2002
3/25/2003
12/09/2003
8/24/2004
05/10/2005
1/24/2006
10/10/2006
6/26/2007
03/11/2008
11/25/2008
08/11/2009
4/27/2010
01/11/2011
9/27/2011
06/12/2012
2/26/2013
11/12/2013
7/29/2014
4/14/2015
12/29/2015
9/13/2016
5/30/2017
itl1q
litl1q

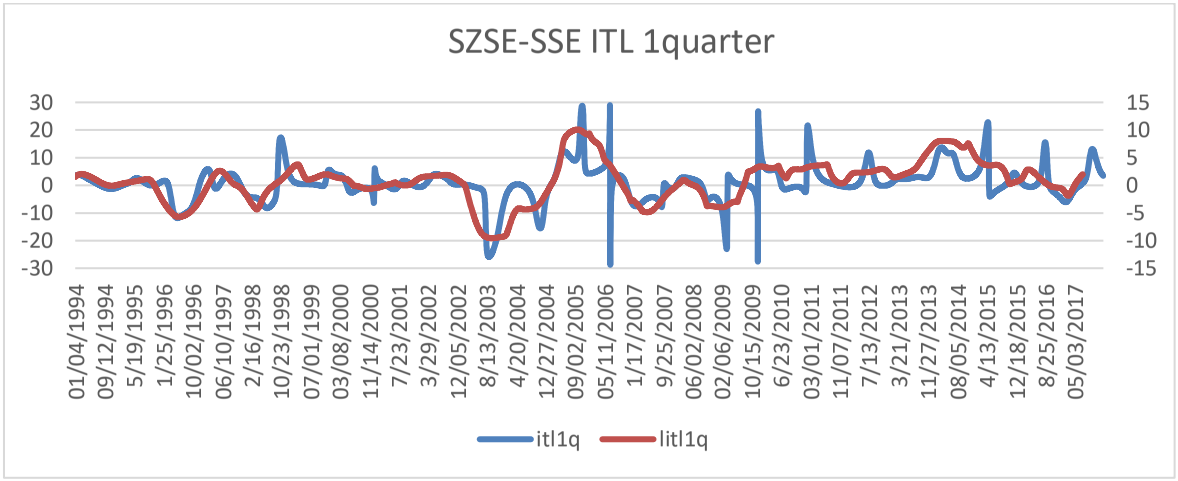

HKSE-SZSE ITL 1year
200
100
0
-100
-200
01/04/1...
9/20/1994
06/06/1...
2/20/1996
11/05/1...
7/22/1997
04/07/1...
12/22/1...
09/07/1...
5/23/2000
02/06/2...
10/23/2...
07/09/2...
3/25/2003
12/09/2...
8/24/2004
05/10/2...
1/24/2006
10/10/2...
6/26/2007
03/11/2...
11/25/2...
08/11/2...
4/27/2010
01/11/2...
9/27/2011
06/12/2...
2/26/2013
11/12/2...
7/29/2014
4/14/2015
12/29/2...
9/13/2016
5/30/2017
itl1y

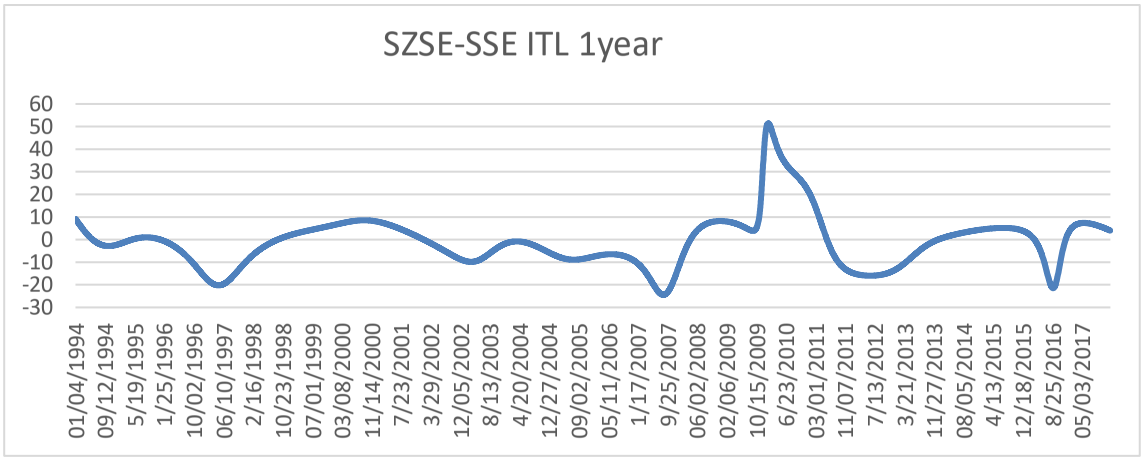

HKSE-SZSE ITL 4years
250
200
150
100
50
0
-50
01/04/1994
9/20/1994
06/06/1995
2/20/1996
11/05/1996
7/22/1997
04/07/1998
12/22/1998
09/07/1999
5/23/2000
02/06/2001
10/23/2001
07/09/2002
3/25/2003
12/09/2003
8/24/2004
05/10/2005
1/24/2006
10/10/2006
6/26/2007
03/11/2008
11/25/2008
08/11/2009
4/27/2010
01/11/2011
9/27/2011
06/12/2012
2/26/2013
11/12/2013
7/29/2014
4/14/2015
12/29/2015
9/13/2016
5/30/2017

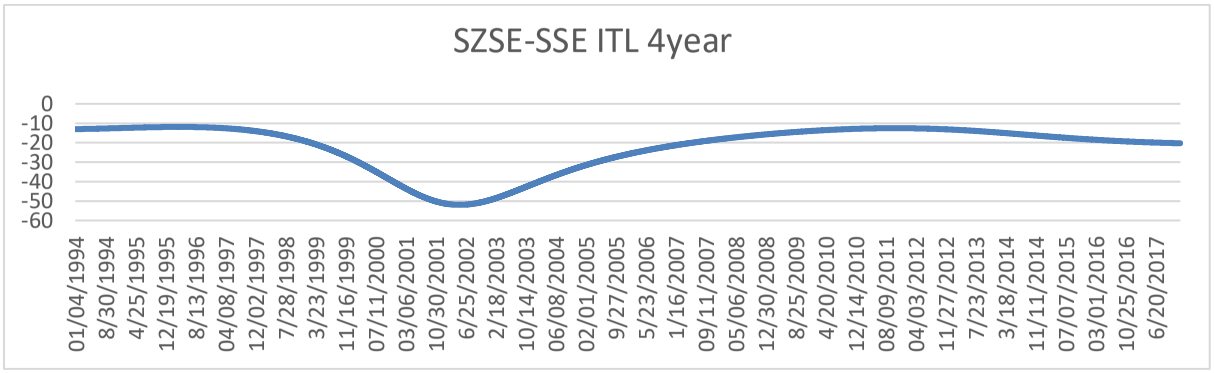
A3.3 ITL for SZSE – SSE relationship








SZSE-SSE ITL 1year
60
50
40
30
20
10
0
-10
-20
-30
01/04/1994
09/12/1994
5/19/1995
1/25/1996
10/02/1996
06/10/1997
2/16/1998
10/23/1998
07/01/1999
03/08/2000
11/14/2000
7/23/2001
3/29/2002
12/05/2002
8/13/2003
4/20/2004
12/27/2004
09/02/2005
05/11/2006
1/17/2007
9/25/2007
06/02/2008
02/06/2009
10/15/2009
6/23/2010
03/01/2011
11/07/2011
7/13/2012
3/21/2013
11/27/2013
08/05/2014
4/13/2015
12/18/2015
8/25/2016
05/03/2017


SZSE-SSE ITL 4year
0
-10
-20
-30
-40
-50
-60
01/04/1994
8/30/1994
4/25/1995
12/19/1995
8/13/1996
04/08/1997
12/02/1997
7/28/1998
3/23/1999
11/16/1999
07/11/2000
03/06/2001
10/30/2001
6/25/2002
2/18/2003
10/14/2003
06/08/2004
02/01/2005
9/27/2005
5/23/2006
1/16/2007
09/11/2007
05/06/2008
12/30/2008
8/25/2009
4/20/2010
12/14/2010
08/09/2011
04/03/2012
11/27/2012
7/23/2013
3/18/2014
11/11/2014
07/07/2015
03/01/2016
10/25/2016
6/20/2017

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