



Master Thesis

**Volatility and Mean Spillover of Chinese ADRs
at New York Stock Exchange**

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Abstract

This paper examines how the returns and volatility of Chinese ADRs listed at NYSE are affected by their host market (US), underlying market (Hong Kong) and local market (Shanghai). Using a GARCH spillover model and data from 1 January 2002 to 30 September 2007, we find that the volatility spillover from US (host market), Hong Kong (underlying market) and Shanghai (local market) to Chinese ADRs, following the order: Hong Kong > US > Shanghai which can also be reflected in variance ratios. The increasing impact from host market and local market may attribute to strengthened integration between Chinese market and world market after China entered WTO. For US investors, they may need to be more prudent in diversification by using Chinese ADRs. However, there is relatively weak mean spillover from US (host market), Hong Kong (underlying market) and Shanghai (local market) to Chinese ADRs. Chinese ADRs including China Mobile Ltd. experience mean spillover from Hong Kong, whereas no mean spillover is found in Chinese ADRs excluding China Mobile Ltd. This difference may due to closer relationship between Hong Kong market and China Mobile Ltd.. Finally, we find symmetric responses in Chinese ADRs to upturns and downturns as well as the positive shocks and negative shocks in the US, Hong Kong and Shanghai markets.

Key words: Chinese ADRs, Hang Seng, S&P 500, Shanghai, volatility, mean, spillover, correlation, GARCH, asymmetries

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1. Introduction

1.1. Background

An examination of the trends in global capital markets over the past few years reveals that many foreign firms have used American Depositary Receipts (ADRs) to list their shares or to raise capital in the US. The ADRs are securities traded in the US, issued by US depository institutions that represent equity shares of foreign-based companies. Generally, the ADRs are issued by a program initiated by a foreign company, and then maintained and administered by a depository bank, based on a deposit agreement between the bank and the company, and they are treated in the same manner as US securities for all legal and administrative purposes.

For US investors, ADRs provide an alternative to investing in overseas equities to diversify their portfolios and earn higher risk-adjusted yields without the inconveniences: a) there is no currency conversion in trading and in receiving dividends, b) they can help in minimizing higher overseas transaction costs and custodial fees, and c) the uniformity in information is available due to mandatory disclosures.

ADRs have been around for almost 80 years. The first ADR was issued by JP Morgan in 1927 for Americans to invest in British retailer Selfridge's. Prior to 1990, the ADRs market was dominated by firms from developed markets, such as Australia, Japan, the Netherlands, Sweden and the UK. However, in the last decade, firms from emerging markets, such as Brazil, China, Chile, Indonesia, and Mexico, have accessed the ADR market and already accounted for over one third ADRs. Based on statistics from the Bank of New York, the dollar trading volume of ADRs has an annual average increase of 30-40 % between 2002 and 2007. Moreover, this tendency that, Non-US issuers play an increasingly important role on the Exchange can also be reflected at NYSE, one of the most important platforms for ADRs. There are approximately 451 Non-US firms listed at NYSE with the total market value 9.6 trillion USD till December 31, 2006.

This prosperity of ADRs is mainly driven by five factors. Firstly, they enable issuers to attract new clientele. Specifically, since ADRs are traded in US dollars and depositories convert all dividends to US dollars, many pension funds and banks whose charters preclude holding foreign securities can invest through ADRs. Secondly, they

provide an easy mechanism to develop an investor base in the US and to raise capital from the US market – leading to a diversification of sources of capital and to a potentially lower cost of capital. Thirdly, they increase potential liquidity by enlarging the market for the company's shares. Fourthly, listed ADRs may serve as pre-commitment devices for the issuing firms to improve shareholder communication. Finally, ADRs facilitate cost-effective bookkeeping since depositaries provide the services of a stock transfer agent and a registrar for both the ADRs as well as the underlying home shares, cf. Amar Gande (1997).

Rapid market integration over the past decade has been characterized by relatively unrestricted cross-border cash flow, the liberalization of financial markets and the global presence of large financial institutions. As a developing country, China initiated its market oriented economy attempt in 1980s by means of “open-up” policy. The momentous event of China's entry to the World Trade Organization (WTO) quickens its financial liberalization and economy globalization, which offers Chinese companies the approach to acquire capital from foreign investors in the form of ADR.

In 21 century, Chinese ADRs increased substantially. Compared to September 2004, it rises up by 93%. Up to 30 Oct 2007, there are eighty-four Chinese ADRs are listed in the US, with twenty-nine traded at NYSE, twenty-nine at NASDAQ and twenty-six at OTC.

1.2. Literature review

The very first studies focusing on ADRs can be dated back to Hoffmeister et al. (1987) who examine forty-five ADRs from 1973 to 1983 and conclude that ADRs are very effective in delivering international diversification benefits. Similar to their results, Wahab and Khandwala (1993) also find diversification gains by analyzing thirty-one ADRs. However, these researches did not use the corresponding foreign country equity portfolios or indices as alternative investment vehicles.

Jiang (1998) address three findings based on empirical study of 113 ADRs from eight countries over the period of 1980-1994. Firstly, ADRs appear to have outperformed their respective local market indices. Secondly, the ADRs are influenced by their respective market index portfolios, while, for countries with cointegrated ADRs and market portfolios, the effect of the ADRs on local market portfolios is relatively stronger. Thirdly, ADRs returns are found to have significant

correlation with US return, as well as local market conditions and exchange rates, suggesting diversification benefits of the ADRs through two sources: a country diversification and currency diversification.

Choi and Kim (2000) investigate major determinants of eighty-seven ADRs and their underlying stock returns, using weekly data from 1990 to 1996. Except for exchange rates, they find that the underlying, host and local markets are important determinants of the ADRs. The relative importance of these markets is found to be dependent on market types (emerging or industrial countries). The result of this study have implications that the ADRs, especially those in emerging markets, offer significant international diversification benefits to US investors.

Alaganar and Bhar (2001) examine the Australian ADRs traded in the US. Using daily data from 1 January 1998 to 31 October 1998 and a VAR framework, they find the ADRs have a low correlation with US stock returns, offering diversification benefits. They also report uni-directional information flow from the underlying Australian stocks to the ADRs and from the US market to the Australian market.

Chen, Chou and Yang (2002) study the price transmission effect between ADRs or GDRs (Globally Depositary Receipts) and their respective underlying shares. Samples covers twenty one sponsored Depositary Receipts issued by Taiwan listing companies from October 8, 1997 to May 31, 2000. Granger tests are used to examine causal relations between the returns of both capital markets. The results reveal unidirectional causality from Taiwan's capital markets to foreign markets. This asymmetry suggests the domestic market plays a dominant role relative to the foreign market. At the same time, the prices of both markets will make opposite adjustment to establish the long run cointegrated equilibrium.

Unfortunately, all these studies do not come down to Chinese ADRs. We consider the Chinese ADRs market starts to spring up just in recent years. This can offer us a possible explanation to the scantiness research involving Chinese ADRs. The only available paper we can find about Chinese ADRs is issued by Kutan and Zhou (2006). They investigate the determinants of returns and conditional volatility of the Chinese ADRs listed at NYSE. The data are selected from 16 April 1998 through 30 September 2004. Results from both low-and high-volume ADRs portfolios show that, underlying (Hong Kong), host (US) and local (Shanghai) markets are all important determinants of returns of the Chinese ADRs. However, the underlying Hong Kong market has the most significant impact on mean returns of the ADRs. In terms of the

conditional volatility of the ADRs returns, the only important determinant is the shocks of underlying markets (Hong Kong). Although there is negative correlation between host (US) market returns and those of the ADRs, the shocks from host market (US) have no significant impact on the conditional volatility (risk) of the ADRs. These results suggest that the ADRs offer significant diversification benefits to US investors.

1.3. Purpose

Although some of the researchers in the previous studies have examined ADRs from various aspects. Most of them focus on ADRs and their underlying stocks in developed countries, and conclude ADRs as an investment tool for international diversification. However, few studies have shed light on Chinese ADRs. As Chinese economy now has much stronger integration into the world market and its financial system has improved extraordinarily, particularly with China entering WTO, we expect Chinese ADRs to continue to play a significant role in the future. This statement motivates us to explore the spillover effect on returns and conditional volatility of Chinese ADRs by their host market (US), underlying market (Hong Kong), and local market (Shanghai, Shenzhen). In this way, we are able to get insight into Chinese ADRs from the point of the determinants of the ADRs and their diversification benefits, and compare these results with previous studies. To our best knowledge, this is the first empirical study on the spillover effect on the Chinese ADRs with their host, underlying and local markets all at the same time.

1.4. Our Hypothesis

Hypothesis I: Determinants of Chinese ADRs

Dual listing of stocks in the case of ADRs naturally raises the question of the relations between the returns of the two markets. Since the underlying stocks of Chinese ADRs are listed in Hong Kong, we can hypothesize that the most important determinant factor of Chinese ADRs comes from Hong Kong. This is in line with the studies on Chinese ADRs by Kutan and Zhou (2006). Moreover, as stated in background, Chinese economy has become more integrated with the world market since China entering WTO in end of 2001. In this sense, US market should be expected to have

more influence on the Chinese ADRs. Concerning the local market (Shanghai and Shenzhen), Chinese ADRs are not that close to local stock market since their underlying market is in Hong Kong. Thus, the local market should be least important in determining Chinese ADRs.

Hypothesis II: Diversification

As documented by all the previous studies, there are diversification gains for US investors to invest in ADRs, due to their independence with US return. However, in our Hypothesis I, the US market is expected to have spillover effect on Chinese ADRs. Therefore, we may have doubt about its diversification benefits. Given that Chinese ADRs are related to US market, little or no diversification from Chinese ADRs may be proposed.

1.5. Outline

The thesis proceeds according to the following structures:

Chapter 2 - Chinese ADRs

In this section, we provide more specific description of Chinese ADRs and the determinants of Chinese ADRs.

Chapter 3 – Data & Preliminary Analysis

This part is dedicated to describing the data and preliminary analysis involving descriptive statistics and correlation of return series.

Chapter 4 - Models

In this part, we present the empirical models of spillover for our data. Constant spillover model, conditional correlation and asymmetric model are set forth by order.

Chapter 5 – Empirical Results

We display the results from our models employed in each sub-section.

Chapter 6 – Conclusions

In this chapter, we conclude our results and discuss their implication compared to previous studies.

2. Chinese ADRs

2.1. Description of Chinese ADRs

About thirteen years ago, China listed its first ADR at NYSE. Before 1997, most Chinese ADRs were issued under OTC or 144A program. However, after 1996, most Chinese ADRs are listed in the New York Stock Exchange. Up to 30 October 2007, there are eighty-four ADRs listed in US, with twenty-nine traded at NYSE, twenty-nine at NASDAQ and twenty-six at OTC. Table A in Appendix shows the twenty-nine Chinese ADRs listed at NYSE. The names of the respective industries along with their initial listing dates are elaborated specifically.

In this paper, we only focus on Chinese ADRs listed at NYSE for study. Moreover, as stated in our purpose, we are interested in ADRs under the background of economy integration after China entering WTO. Thus, we only select those ADRs issued before 2002 to get more mature ADRs with sufficient sample period. In Table 1, we specify eleven ADRs included in our study.

In this paper, we take the approach of constructing ADRs portfolio to capture price and volatility linkages between the ADRs and their corresponding markets, since we think the portfolio is a better proxy to represent the overall performance of eleven ADRs. We consider the market-value-weighted ADRs portfolio and also show the average market capitalization of eleven Chinese ADRs in Table 1. There is very notable in the market capitalization that China Mobile Ltd. (CHL) is superior in numbers, taking up 71% in the whole ADRs. Under these circumstances, it maybe better to construct two portfolios using China Mobile Ltd. as a benchmark.

Table 1: Chinese ADRs listed at NYSE (up to Dec, 2001)

Name	Ticker	Ratio	Industry sector	Underlying ADRs	Effective date	Average Market Cap (\$thousand)
Sinopec Shanghai Petrochemical Co.Ltd.	SHI	1 : 100	Chemicals	HK 0338	July 1993	1023622
Huaneng Power International Inc.	HNP	1 : 40	Electric utility	HK 0902	October 1994	2434207
Guangshen Railway Co.Ltd.	GSH	1 : 50	Transportation	HK 0525	May 1996	643728
China Eastern Airlines Corp.Ltd.	CEA	1 : 100	Airlines	HK 0670	February 1997	509990
China Southern Airlines Co.Ltd.	ZNH	1 : 50	Airlines	HK 1055	July 1997	645244
China Mobile Ltd.	CHL	1 : 5	Telecommunications	HK 0941	October 1997	140937388
Yanzhou Coal Mining Co.Ltd.	YZC	1 : 50	Mining	HK 1171	March 1998	1751208
Petrochina Co.Ltd.	PTR	1 : 100	Oil and gas	HK 0857	April 2000	20295353
China Unicom Ltd.	CHU	1 : 10	Telecommunications	HK 0762	June 2000	14897332
China Petroleum&Chemical Corp.	SNP	1 : 100	Oil and gas	HK 0386	October 2000	11013630
Aluminum Corp. of China Ltd.	ACH	1 : 25	Mining	HK 2600	December 2001	3651708

2.2. Determinants of Chinese ADRs returns

According to the pricing theory, the returns of ADRs should approach to returns of their underlying stocks, after taking into consideration of transaction costs and risk factors, cf. Kim, Szakmary and Mathur (2000). They find that the most influential factor in pricing the ADRs in Japan, UK, Sweden, the Netherlands and Australia is their underlying shares, as well as exchange rate and US market. Hence, the movements in the underlying and host markets as well as exchange rate in host markets should reflect changes in the ADRs prices.

Whereas, the pricing behavior of the Chinese ADRs at NYSE is supposed to be different from those of ADRs in developed and other emerging countries. Normally, the underlying markets of ADRs are also their local markets. However, it is shown in Table 1 and Appendix Table A, that for most Chinese ADRs, the underlying market is Hong Kong Stock Exchange, instead of their local Shanghai Stock Exchange and Shenzhen Stock Exchange. This is probably because Hong Kong is one of the world's most mature financial markets, which operates over forty years earlier than Shanghai and Shenzhen, and hence can provide a more convenient access for a number of firms in Mainland China to US stock market after it was taken over by China in 1997. Therefore, we employ Hong Kong market as the underlying market of Chinese ADRs. In this paper, the underlying market (Hong Kong) is represented by Hang Seng Index which is the main indicator of the overall market performance in Hong Kong. It is a freefloat-adjusted market capitalization-weighted stock market index in Hong Kong and is used to record and monitor daily changes of the largest companies of the Hong Kong stock market.

The other factors in pricing Chinese ADRs are their host market (US) and exchange rates. We exclude the potential effect of exchange rate since Hong Kong has been pegging its currency to US dollars since 1983 through a currency board system, which requires both the stock and the flow of monetary base to be fully backed by foreign reserves. Any change in the size of the monetary base to be fully matched by a corresponding change in the foreign reserves, cf. Kutan and Zhou (2006). Considering the host market, we employ S&P 500 to represent the performance of US stock market. S&P 500 is an index containing the stocks of 500 Large- Cap companies in

leading industries of US economy and is considered to be a bellwether for US economy and is a component of the Index of Leading Indicators.

Moreover, we extend the determinants of Chinese ADRs by taking the local markets (Shanghai, Shenzhen) into consideration. The increasing integration with global capital market will reasonably enhance the impact of Chinese stock market after China entered to WTO. Any news from local market may transmit to Chinese ADRs and reflected in their returns. There are two stock markets in Mainland China: Shanghai Stock Exchange and Shenzhen Stock Exchange. Most of large and state-owned companies are listed on Shanghai Stock Exchange while relatively small, joint ventures and export-oriented companies are listed on Shenzhen Stock Exchange. We use Shanghai SE composite and Shenzhen SE composite to capture the performance of China stock market. Both of them are capitalization-weighted indices by tracking the daily price performance of all shares listed on the Shanghai or Shenzhen Stock Exchange market.

3. Data and Preliminary Analysis

3.1. Data

The raw data employed in this paper are daily closing equity prices of eleven Chinese ADRs listed at NYSE, the market capitalization of eleven Chinese ADRs each year and four stock market daily indices of S&P 500, Hang Seng index, Shanghai SE composite and Shenzhen SE composite. The data were retrieved from the DataStream International. Shanghai SE Composite and Shenzhen SE composite are used to represent the Mainland China stock market, Hang Seng index is utilized to represent the underlying market since all eleven Chinese ADRs at NYSE are listed in Hong Kong market. The host market is represented by S&P 500 index. All data are measured in terms of US dollars. The sample period is from 1 January 2002 to 30 September 2007.

The Chinese ADRs portfolio is constructed as the market-value-weighted portfolio. For each Chinese ADR, we calculated the average market capitalization during the sample period and obtained the ratio of each Chinese ADR in the sum of eleven Chinese ADRs market capitalization. This ratio represents the weight of each ADR in the sample period and thus is considered to be appropriate for constructing the ADRs

portfolio. In this way, we obtain the Chinese ADRs portfolio by multiplying individual Chinese ADR returns with the corresponding weight. It is extraordinarily noted that China Mobile Ltd. amount to 71.25% in the Chinese ADRs portfolio since it owns up to nearly 140 billion while the eleven Chinese ADRs only sum up to 198 billion. In order to check if there is a structural change in the return and volatility spillover effects driven by China Mobile Ltd., we separate Chinese ADRs (inc) and Chinese ADRs (exl) by employing China Mobile Ltd. as the benchmark. The Chinese ADRs (inc) is denoted as the constructed portfolio which includes all eleven ADRs, and the Chinese ADRs (exl) is denoted as the ADRs portfolio which excludes the China Mobile Ltd..

Using daily stock price and indices covering from 1 January 2002 to 30 September 2007 is more beneficial since it gives us a relatively long sample period with a relatively large sample of the ADRs. Moreover, this period follows the major event of China entered WTO, where we posit that the spillover effects are expected to be different from studies before 2002. Close-to-close daily returns are used for all prices and indices even though the weekly data are preferred by Burns and Engle (1998), Ng (2000) who argued that weekly data can avoid the problems of non-synchronous trading and the day-of-the-week effects since largely overlap is shared among markets. Concerning our purpose which takes market correlation into consideration, high frequency data (daily data) is, however, more practical for studying international correlations and spillover, cf. Eun and Shim (1989); Karolyi and Stulz (1996).

Subsequently, all data are applied in the form of daily returns. The daily stock returns are calculated as the natural logarithm of the stock price relative, namely, $\log(c_t) - \log(c_{t-1})$.

3.2. Descriptive statistics

Table 2 presents several summary statistics for the daily returns of the four stock markets and two constructed Chinese ADRs portfolios. The average daily returns are all positive and fall in a fairly dispersed range; from 0.0002\$ (S&P 500) to 0.0012\$ (Chinese ADRs exl). Over the whole sample, both of two Chinese ADRs portfolios have the higher mean compared to other four stock markets. It is clear that the mean returns and volatility for Shanghai and Shenzhen are higher than S&P 500 and Hang

Seng index. This result is common for emerging market (Mainland China) and is consistent with Harvey and Bekaert (1995).

The skewness and kurtosis numbers for all returns distribution indicate a highly leptokurtic, non-normal distribution for all daily returns in sample. The Jarque-Bera (1980) test statistics rejects the null of normality of returns for all series. Some of the return series are significantly autocorrelated (Ljung-Box (1978) tests for order and up to sixth order autocorrelation). Thus, there are indications that the AR specification is useful. The Ljung-Box (LB) Q statistics for the squared returns are much higher than those of the raw returns, suggesting the presence of time-varying volatility, cf. Y. Angela Liu and Ming-Shiun Pan (1997). The squared returns of four price indices show the behavior of volatility clustering and heteroskedasticity of the four markets and the ADRs portfolio (See Figure 2) which is consistent with above statement. Thus, this descriptive analysis of return data motivates the use of GARCH model to capture the properties of returns, including fat tails, non-normality and time-varying volatility found in these stock return series.

Table 2: Descriptive statistics of the return series^a

	RSP	RHS	RSH	RSZ	ADRs(inc)	ADRs(exl)
Mean	0.0002	0.0006	0.0009	0.0008	0.0011	0.0012
Median	0.0003	0.0001	1.43E-05	0.0001	0.0003	0.0008
Maximum	0.0557	0.0572	0.0885	0.0867	0.0799	0.0924
Minimum	-0.0424	-0.0422	-0.0910	-0.0877	-0.1019	-0.0825
Std. Dev.	0.0098	0.0103	0.01455	0.0156	0.0192	0.0176
LB	6.8815 (0.142)	4.8330 (0.305)	6.8815 (0.142)	11.5940 (0.021)	17.5600 (0.002)	10.6400 (0.100)
LB2(6)	523.12 (0.000)	68.2830 (0.000)	61.9590 (0.000)	125.9900 (0.000)	49.8230 (0.000)	193.2000 (0.000)
Skewness	0.1551	0.0495	-0.0538	-0.2187	-0.0238	0.0202
Kurtosis	6.2485	4.7932	7.8153	6.9621	4.3893	5.4557
Jarque-Bera	664.6740	201.3210	1447.9990	991.7776	120.6195	376.4898
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	0.2851	0.8714	1.31356	1.2672	1.6300	1.8377
Sum Sq. Dev.	0.1451	0.1597	0.3171	0.3620	0.5520	0.4628
Observations	1498	1498	1498	1498	1498	1498

^a All daily returns are calculated by $\log(c_t) - \log(c_{t-1})$ in US dollars from 1 January 2002 to 30 September 2007. LB (6) is the Ljung-Box Q statistics for order 6 serial correlation, which distribute as a chi-square variate with 6 degree of freedom. P-values are given in parentheses at the 5% level.

3.3. Correlation

The returns correlation matrix is shown in Table 3 and Table 4. High correlation is observed between the Chinese ADRs portfolio (inc) and US market with a coefficient of 0.548, followed by Hong Kong market (0.536). While Shanghai and Shenzhen seem to have low correlation with Chinese ADRs (inc). The similar pattern of correlation is noted in Chinese ADRs portfolio (exl), while the relationship between ADRs (exl) with US and Hong Kong drops to 0.473 and 0.470, respectively. Correspondingly, the correlation with Shanghai and Shenzhen increase to 0.142 and 0.115.

It is important to note that there is a significant high correlation between Shanghai and Shenzhen Markets which is 0.945. Seen also from Figure 1 and Figure 2, the returns of Shanghai and Shenzhen share almost the same tendency. Therefore, we propose to take only Shanghai market as the representative of Mainland China market, in order to eliminate the impact of the significant multicollinearity among the explanatory variables.

Table 3: Correlation matrix of return series (ADRs inc)

	US	Hong Kong	Shanghai	Shenzhen	ADRs(inc)
US	1.000				
Hong Kong	0.115	1.000			
Shanghai	0.022	0.145	1.000		
Shenzhen	0.019	0.130	0.945	1.000	
ADRs (inc)	0.548	0.536	0.117	0.099	1.000

Table 4: Correlation matrix of return series (ADRs exl)

	US	Hong Kong	Shanghai	Shenzhen	ADRs(exl)
US	1.000				
Hong Kong	0.115	1.000			
Shanghai	0.022	0.145	1.000		
Shenzhen	0.019	0.130	0.945	1.000	
ADRs (exl)	0.473	0.470	0.142	0.115	1.000

4. Models

This paper intends to investigate the spillover effect on both returns and volatility of Chinese ADRs listed at NYSE by US, Hong Kong and Mainland markets. It is well-

documented that the distribution of stock returns is characterized with fat tails and high peakness. Various models have been proposed in earlier studies to capture this property, among them, GARCH models proposed by Engle (1982) and Bollerslev (1986) are appearing since they can capture the fat-tailed nature of the distribution and presence of time-varying volatility. Empirical evidence further showed that GARCH(1, 1) is found to be a good fit for asset returns, e.g., Bollerslev, Chou and Kroner (1992) for a survey.

In the previous studies on Chinese ADRs, GARCH models have been conducted by Kutun and Zhou (2006) who focuses on determinants of returns and volatility of Chinese ADRs by Hong Kong, US and Shanghai stock markets. They don't exam the spillover effect of Chinese ADRs. They only consider the mean and volatility effect of Chinese ADRs by adding two of seven stock markets indices at a time in the mean equation of Chinese ADRs in one step; and repeat this procedure for other two of seven indices, etc, without including the US, Hong Kong, and Mainland residuals in the mean equation of Chinese ADRs. Nevertheless, there is support provided by Bessler and Yang (2003) that there are interdependencies among national stock markets. This implies that cross-country correlation is known to enable risk exposure moving together, and the cross-country shocks will affect the outsider returns. In this term, the volatility spillover effect should be taken into account in the model selection.

Our spillover model is based on the models specified by Bekaert and Harvey (1997), Ng (2000), Baele (2002) and Christiansen (2003) who all consider volatility-spillover effects on the international stock or bond markets.

Ng (2000), who examines the magnitude and changing nature of volatility spillover effect from the US (global effect) and Japan (regional effects) to six Pacific-Basin equity markets, construct two-step spillover model. In the first step, a bivariate GARCH (1, 1) model for the Japanese and US returns is estimated by numerical maximum likelihood. The result shows there are no spillover effects between the US and Japan. In the second step, contemporary US and Japan innovations from the first-step regression are used along with the one-period lagged US and Japanese returns to explain the equity return of the individual Pacific-Basin countries. He included the spillover effects from two categories: constant spillover effects and time-varying spillover effects.

Christiansen (2003) similarly analyzes volatility spillover model from the US (global effect) and aggregate European bond market (regional effect) into individual

European bond markets, but instead in three steps. In the first step, a univariate AR-GARCH model is estimated for the US return. In the second step, an extended univariate AR-GARCH model is estimated for the aggregate European return. The US residual from the first-step regression is included as an explanatory variable. Finally, in the third step, a univariate extended AR-GARCH model for the return of the individual European country is estimated. Both the US and European residuals from the two first steps are included as explanatory variables. In this way, the model allows two sources of volatility-spillover effects. Compared to Ng (2000), this three-step estimation procedure distinguishes itself by avoiding orthogonalization between the idiosyncratic shocks of the US and European bond markets. Two kinds of spillover effects, namely, constant spillover effect and time-varying spillover effect are employed.

By looking at these two models - the explicit structure in the three-step procedure without orthogonalization or the implicit structure in two-step procedure with orthogonalization, the previous one is preferred in this paper for two reasons. First, it can avoid orthogonalization between idiosyncratic shocks from outside markets and own market in a parsimonious way. Second, it can allow for causality going from the US to Hong Kong, and from Hong Kong to Mainland China which is supported by Granger causality tests, cf. Granger (1969).

Hence, we imply the similar approach to Christiansen, but extend into a four-step model in which unexpected returns on Chinese ADRs at NYSE are influenced not only by its idiosyncratic shocks but also by three stock markets shocks-shock of US stock market (host market), Hong Kong stock market (underlying market), and Shanghai market (local market). In this term, we grasp the intuitive appeal of moving from US (world effects) to Hong Kong and Mainland China (regional effects)

The subsequent analysis relies on four-step univariate AR-GARCH (1, 1) using one-period lagged returns of Hong Kong, US and Shanghai and contemporary idiosyncratic shocks of US, Hong Kong and Shanghai stock markets as explanatory variables for Chinese ADRs. In this way, our model can avoid orthogonalization between idiosyncratic shocks among US, Hong Kong and Shanghai stock markets, with the causality going from the US to Hong Kong and Shanghai stock markets. Moreover, the variance ratio which measures the proportions of variance of Chinese ADRs' unexpected returns accounted by the US, Hong Kong and Shanghai factors respectively is followed. Finally, asymmetric spillover model is applied to examine

the existence of asymmetric response. The spillover effect is assumed as constant in this paper.

4.1. Constant Spillover Model

The conditional return on the US: S&P 500 index, $R_{US,t}$ is assumed to evolve according to an AR (1) process

$$R_{US,t} = c_{0,US} + c_{1,US}R_{US,t-1} + e_{US,t} \quad (1)$$

Where $e_{US,t}$ is the purely idiosyncratic shock which is assumed to follow normal distribution with mean zero and the conditional variance $\sigma_{US,t}^2$ follows a symmetric GARCH (1, 1) specification, cf. Engle (1982) and Bollerslev (1986):

$$\sigma_{US,t}^2 = \omega_{US} + \alpha_{US}e_{US,t-1}^2 + \beta_{US}\sigma_{US,t-1}^2 \quad (2)$$

Where $\omega_{US} > 0$ and $\alpha_{US}, \beta_{US} > 0$ to make sure the variance is positive.

The return on the Hong Kong: Hang Seng index $R_{HK,t}$ is assumed to be described by the following extended AR (1) specification:

$$R_{HK,t} = c_{0,HK} + c_{1,HK}R_{HK,t-1} + \gamma_{HK,t-1}R_{US,t-1} + \phi_{HK,t-1}e_{US,t} + e_{HK,t} \quad (3)$$

The conditional mean of Hong Kong return depends on the own lagged returns as well as the lagged US return. The mean spillover effects are introduced by the lagged US return, $R_{US,t-1}$. The volatility spillover from the US to Hong Kong takes place via the US idiosyncratic shock, $e_{US,t}$. Thus, the Hong Kong return depends on the US idiosyncratic shock. The idiosyncratic shock ($e_{HK,t}$) has mean 0 and the conditional variance evolves according to the GARCH (1, 1).

$$\sigma_{HK,t}^2 = \omega_{HK} + \alpha_{HK}e_{HK,t-1}^2 + \beta_{HK}\sigma_{HK,t-1}^2 \quad (4)$$

Where we require that $\omega_{HK} > 0$, $\alpha_{HK}, \beta_{HK} \geq 0$

The third step consists in providing a model for Shanghai Stock market return. The mean specification for the Hong Kong return in equation (3) is extended even further.

$$R_{SH,t} = c_{0,SH} + c_{1,SH}R_{SH,t-1} + \gamma_{SH,t-1}R_{US,t-1} + \delta_{SH,t-1}R_{HK,t-1} + \phi_{SH,t-1}e_{US,t} + \psi_{SH,t-1}e_{HK,t} + e_{SH,t} \quad (5)$$

The conditional Shanghai stock market return depends on the lagged US, Hong Kong and own return. This specification allows mean spillover effects from both the US and Hong Kong returns to Shanghai stock market by the lagged returns $R_{US,t-1}$ and $R_{HK,t-1}$. Volatility spillover effects from the US and Hong Kong to the Shanghai stock market are introduced by the variable $e_{US,t}$ and $e_{HK,t}$, respectively, i.e. the idiosyncratic US and Hong Kong shocks. The idiosyncratic shocks $e_{SH,t}$, has mean 0 and the conditional variance $\sigma_{SH,t}^2$, evolves according to the GARCH (1, 1):

$$\sigma_{SH,t}^2 = \omega_{SH} + \alpha_{SH}e_{SH,t-1}^2 + \beta_{SH}\sigma_{SH,t-1}^2 \quad (6)$$

Where we again require $\omega_{SH} > 0$, $\alpha_{SH}, \beta_{SH} \geq 0$

The last step consists in providing a model for the market-value-weighted Chinese ADRs portfolio returns. The mean specification is:

$$R_{ADR,t} = c_{0,ADR} + c_{1,ADR}R_{ADR,t-1} + \gamma_{ADR,t-1}R_{US,t-1} + \delta_{ADR,t-1}R_{HK,t-1} + \varphi_{ADR,t-1}R_{SH,t-1} + \phi_{ADR,t-1}e_{US,t} + \psi_{ADR,t-1}e_{HK,t} + \zeta_{ADR,t-1}e_{SH,t} + e_{ADR,t} \quad (7)$$

The US, Hong Kong and Shanghai stock markets returns have mean spillover effects to the Chinese ADRs by the lagged returns $R_{US,t-1}$, $R_{HK,t-1}$ and $R_{SH,t-1}$. Volatility spillover effects from the US, Hong Kong and Shanghai to the Chinese ADRs take place via the variables $e_{US,t}$, $e_{HK,t}$ and $e_{SH,t}$, i.e. the idiosyncratic US, Hong Kong and Shanghai shocks. The idiosyncratic shock of the Chinese ADRs ($e_{ADR,t}$) is subject to the same distribution assumptions as the US, Hong Kong and Shanghai idiosyncratic shocks. It has mean 0 and conditional variance $\sigma_{ADR,t}^2$ following the GARCH (1, 1):

$$\sigma_{ADR,t}^2 = \omega_{ADR} + \alpha_{ADR}e_{ADR,t-1}^2 + \beta_{ADR}\sigma_{ADR,t-1}^2 \quad (8)$$

Where we require $\omega_{ADR} > 0$, $\alpha_{ADR}, \beta_{ADR} \geq 0$

The idiosyncratic shocks $e_{US,t}, e_{HS,t}, e_{SH,t}, e_{ADR,t}$ (for $I=1, \dots, N$) are assumed to be independent. Thus, the unexpected returns ε_t of Chinese ADRs portfolio, US, Hong Kong and Shanghai are described by equation (9), (10), (11) and (12) as follows:

$$\varepsilon_{US,t} = e_{US,t} \quad (9)$$

$$\varepsilon_{HK,t} = \phi_{HK,t-1} e_{US,t} + e_{HK,t} \quad (10)$$

$$\varepsilon_{SH,t} = \phi_{SH,t-1} e_{US,t} + \psi_{SH,t-1} e_{HK,t} + e_{SH,t} \quad (11)$$

$$\varepsilon_{ADR,t} = \phi_{ADR,t-1} e_{US,t} + \psi_{ADR,t-1} e_{HK,t} + \zeta_{ADR,t-1} e_{SH,t} + e_{ADR,t} \quad (12)$$

$$E[e_{i,t}, e_{j,t} | I_{t-1}] = 0 \quad (13)$$

$$E[e_{i,t}, \varepsilon_{w,t} | I_{t-1}] = 0 \quad (14)$$

The unexpected returns for Chinese ADRs portfolio depends on the contemporary US, Hong Kong, Shanghai and its own idiosyncratic shocks. The sign and significance of the parameter $\phi_{ADR,t-1}$, $\psi_{ADR,t-1}$ and $\zeta_{ADR,t-1}$ determine whether the idiosyncratic shocks from the US, Hong Kong and Shanghai are present in the unexpected returns of Chinese ADRs listed at NYSE respectively. The unexpected return of Shanghai depends on the Hong Kong, US and its own idiosyncratic shocks. The unexpected return of Hong Kong depends only on US and its idiosyncratic shocks. For the unexpected return of the US, it is equivalent to the US idiosyncratic shock.

This definition of the unexpected return above enables us to calculate the conditional variance of the unexpected returns for Chinese ADRs portfolio, denoted as $h_{ADR,t}$. It is based on the information available at time t-1 (I_{t-1}) is given as follows:

$$h_{US,t} = E(\varepsilon_{US,t}^2 | I_{t-1}) = \phi_{US,t-1}^2 \sigma_{US,t}^2 \quad (14)$$

$$h_{HK,t} = E(\varepsilon_{HK,t}^2 | I_{t-1}) = \phi_{HK,t-1}^2 \sigma_{US,t}^2 + \sigma_{HK,t}^2 \quad (15)$$

$$h_{SH,t} = E(\varepsilon_{SH,t}^2 | I_{t-1}) = \phi_{SH,t-1}^2 \sigma_{US,t}^2 + \psi_{SH,t-1}^2 \sigma_{HK,t}^2 + \sigma_{SH,t}^2 \quad (16)$$

$$h_{ADR,t} = E(\varepsilon_{ADR,t}^2 | I_{t-1}) = \phi_{ADR,t-1}^2 \sigma_{US,t}^2 + \psi_{ADR,t-1}^2 \sigma_{HK,t}^2 + \zeta_{ADR,t-1}^2 \sigma_{SH,t}^2 + \sigma_{ADR,t}^2 \quad (17)$$

The conditional variance of the unexpected returns for Chinese ADRs portfolio depends on the variance of the contemporary US, Hong Kong, Shanghai and its own idiosyncratic shocks. When e.g. the underlying market of Chinese ADRs portfolio,

Hong Kong, idiosyncratic volatility is large, the volatility of the unexpected returns for Chinese ADRs portfolio also tends to be large (small) if $\psi_{ADR,t-1}$ is positive (negative). The conditional variance of the Shanghai unexpected return relies on the idiosyncratic volatility of US, Hong Kong and its unexpected return. The conditional variance of the Hong Kong unexpected return depends on the variance of US and its own unexpected return. As for US, the conditional variance of the unexpected return is equivalent to the variance of its own idiosyncratic shock.

Shortly, it will become clear why our model above corresponds to the mean and volatility spillover effects of Chinese ADRs portfolio which is exactly what we want to explore in this paper, cf. equation (7) and equation (17), respectively. Specifically, the mean spillover effect occurs, since the mean equation of Chinese ADRs portfolio allows for one-period lagged US, Hong Kong and Shanghai returns and for the current residuals of US, Hong Kong and Shanghai, cf. equation (7). Based on this, the volatility spillover effect is introduced by adding the impact of the present volatility of unexpected returns from US, Hong Kong and Shanghai markets, cf. equation (17).

4.2. Conditional Correlation

We focus on three statistics concerning the conditional correlation among US, Hong Kong, Shanghai and Chinese ADRs portfolio.

4.2.1. Correlation

The conditional covariance between the unexpected returns of Chinese ADRs portfolio and the US (Hong Kong, Shanghai) unexpected return depends on the US (US, Hong Kong and Shanghai) idiosyncratic volatilities:

$$h_{ADR-US,t} = E(\varepsilon_{ADR,t}\varepsilon_{US,t} | I_{t-1}) = \phi_{ADR,t-1}\sigma_{US,t}^2 \quad (18)$$

$$h_{ADR-HK,t} = E(\varepsilon_{ADR,t}\varepsilon_{HK,t} | I_{t-1}) = \phi_{ADR,t-1}\phi_{HK,t-1}\sigma_{US,t}^2 + \psi_{ADR,t-1}\sigma_{HK,t}^2 \quad (19)$$

$$h_{ADR-SH,t} = E(\varepsilon_{ADR,t}\varepsilon_{SH,t} | I_{t-1}) = \phi_{ADR,t-1}\phi_{SH,t-1}\sigma_{US,t}^2 + \psi_{ADR,t-1}\psi_{SH,t-1}\sigma_{HK,t}^2 + \zeta_{ADR,t-1}\sigma_{SH,t}^2 \quad (20)$$

The conditional correlations between the unexpected returns of Chinese ADRs portfolio and the US (Hong Kong, Shanghai) unexpected return depends on the US (US, Hong Kong and Shanghai) idiosyncratic volatilities as follows:

$$\rho_{ADR-US,t} = \frac{h_{ADR-US,t}}{\sqrt{h_{ADR,t}h_{US,t}}} = \frac{\phi_{ADR,t-1}\sigma_{US,t}}{\sqrt{h_{ADR,t}}} \quad (21)$$

$$\rho_{ADR-HK,t} = \frac{h_{ADR-HK,t}}{\sqrt{h_{ADR,t}h_{HK,t}}} = \frac{\phi_{ADR,t-1}\phi_{HK,t-1}\sigma_{US,t}^2 + \psi_{ADR,t-1}\sigma_{HK,t}^2}{\sqrt{h_{ADR,t}h_{HK,t}}} \quad (22)$$

$$\rho_{ADR-SH,t} = \frac{h_{ADR-SH,t}}{\sqrt{h_{ADR,t}h_{SH,t}}} = \frac{\phi_{ADR,t-1}\phi_{SH,t-1}\sigma_{US,t}^2 + \psi_{ADR,t-1}\psi_{SH,t-1}\sigma_{HK,t}^2 + \zeta_{ADR,t-1}\sigma_{SH,t}^2}{\sqrt{h_{ADR,t}h_{SH,t}}} \quad (23)$$

4.2.2. Variance Ratios

We measure the proportion of the variance of the unexpected returns of Chinese ADRs, cf. equation (17), which is caused by the US, Hong Kong and Shanghai volatility-spillover effects. The variance ratios are defined as follows:

$$VR_{ADR,t}^{US} = \frac{\phi_{ADR,t-1}^2\sigma_{US,t}^2}{h_{ADR,t}} \quad (24)$$

$$VR_{ADR,t}^{HK} = \frac{\psi_{ADR,t-1}^2\sigma_{HK,t}^2}{h_{ADR,t}} \quad (25)$$

$$VR_{ADR,t}^{SH} = \frac{\zeta_{ADR,t-1}^2\sigma_{SH,t}^2}{h_{ADR,t}} \quad (26)$$

The variance ratio takes on value between 0 and 1. The remaining part of the variance of the unexpected returns for Chinese ADRs is caused by pure local effects:

$$VR_{ADR,t}^{ADR} = 1 - VR_{ADR,t}^{US} - VR_{ADR,t}^{HK} - VR_{ADR,t}^{SH} \quad (27)$$

The six parameters in equation (7) differentiate the various spillover models. Since the spillover effect is assumed to be constant, the following equations hold.

$$\begin{aligned} \gamma_{ADR,t} &= \gamma_{ADR} \\ \delta_{ADR,t} &= \delta_{ADR} \\ \varphi_{ADR,t} &= \varphi_{ADR} \\ \phi_{ADR,t} &= \phi_{ADR} \\ \psi_{ADR,t} &= \psi_{ADR} \\ \zeta_{ADR,t} &= \zeta_{ADR} \end{aligned} \quad \forall t \quad (28)$$

4.3. Asymmetric spillover model

We also use asymmetric mean equation to examine whether the returns of the Chinese ADRs respond asymmetrically to the upturns and downturns as well as positive and negative shocks in the US, Hong Kong and Shanghai markets.

$$\begin{aligned}
R_{ADR,t} = & c_{0,ADR} + c_{1,ADR}R_{ADR,t-1} + \gamma_{1,ADR}R_{US,t-1}^+ + \gamma_{2,ADR}R_{US,t-1}^- + \delta_{1,ADR}R_{HK,t-1}^+ \\
& + \delta_{2,ADR}R_{HK,t-1}^- + \varphi_{1,ADR}R_{SH,t-1}^+ + \varphi_{2,ADR}R_{SH,t-1}^- + \phi_{1,ADR}e_{US,t}^+ + \phi_{2,ADR}e_{US,t}^- \quad (29) \\
& + \psi_{1,ADR}e_{HK,t}^+ + \psi_{2,ADR}e_{HK,t}^- + \zeta_{1,ADR}e_{SH,t}^+ + \zeta_{2,ADR}e_{SH,t}^- + e_{ADR,t}
\end{aligned}$$

Where $R_{t-1}^+ = R_{t-1}$ if $R_{t-1} > 0$ and 0 otherwise;

$R_{t-1}^- = R_{t-1}$ if $R_{t-1} < 0$ and 0 otherwise;

$e_t^+ = e_t$ if $e_t > 0$ and 0 otherwise;

$e_t^- = e_t$ if $e_t < 0$ and 0 otherwise.

5. Empirical Results

In the first part of this section, we estimate the constant spillover model. Chinese ADRs portfolio including China Mobile Ltd. is estimated separately with Chinese ADRs portfolio excluding China Mobile Ltd. Secondly, conditional correlation of unexpected returns between Chinese ADRs portfolio and US, Hong Kong and Shanghai is obtained. Subsequently, the asymmetric spillover is estimated.

5.1. Constant Spillover Model

Constant Spillover Model is estimated by the equations (1) – (8) for the period from Jan 2002 to Sep 2007. The results for the estimated coefficients from constant spillover model are presented in Table 5. Table 6 shows the robust Wald tests for five different joint hypotheses of spillover effects, namely, no US spillover effects, no Hong Kong spillover effects, no Shanghai spillover effects, no mean spillover effects, and no volatility spillover effects.

In the first step, we estimate the univariate model for the US return; cf. the first row of Table 5. The parameter of AR (1), $\hat{c}_{1,US}$ is small, negative and significant, which implies weak negative first-order autocorrelation. The variance of the US return is stationary, since $\hat{\alpha}_{US} + \hat{\beta}_{US} \leq 1$.

The second row of Table 5 provides the results from the second step of the estimation of the constant spillover model, specifically, for the return of the Hong Kong stock market. It is obvious that the lagged return of Hong Kong is of minor significance to its own return; as the coefficient $\hat{c}_{1,HK}$ is small, negative and insignificant. Comparably, US lagged return is big, positive and significant to the return of Hong Kong. The coefficient of the contemporary US residual is significant in explaining the current Hong Kong return. Thus, there is evidence of both mean and volatility spillover effects from US to Hong Kong stock market, i.e. $\hat{\gamma}_{HK}$ is significantly positive, which is evidence of mean spillover, i.e. $\hat{\phi}_{HK}$ is significantly positive, implying the volatility spillover. This is reasonable since Hong Kong and US economies are expected to be closely linked given that the Hong Kong dollar has been pegged at a fixed rate against the US dollar since 1983, cf. Kutan and Zhou (2006). Again, the volatility process is shown to be stationary for $\hat{\alpha}_{HK} + \hat{\beta}_{HK} \leq 1$.

In the third step, we continue to estimate the constant spillover model for Shanghai market. Own lagged, US lagged, Hong Kong lagged and US contemporary residual are not significant to the return of Shanghai stock market. In contrast, the contemporary residual of Hong Kong is relatively big and significant to explain the current Shanghai stock return. Therefore, there is no evidence of mean spillover from the US and Hong Kong to Shanghai stock market, i.e. $\hat{\gamma}_{SH}$ and $\hat{\delta}_{SH}$ are small and insignificant, no evidence of mean spillover, while strong evidence of volatility effect is reflected from Hong Kong to Shanghai market, i.e. $\hat{\psi}_{SH}$ is significant. No volatility spillover effect from US to Shanghai is observed, i.e. $\hat{\phi}_{SH}$ is insignificant. The volatility process is stationary as $\hat{\alpha}_{SH} + \hat{\beta}_{SH} \leq 1$.

In the end of the estimation steps, we apply the models for Chinese ADRs (inc) and Chinese ADRs (exl) respectively. The models contain one-period lagged returns and contemporary residuals of the US, Hong Kong and Shanghai markets, thus allow the mean and volatility spillover from US, Hong Kong and Shanghai markets to Chinese ADRs (inc) and Chinese ADRs (exl) respectively. The results for these are presented in the bottom rows of Table 5. For both Chinese ADRs (inc) and Chinese ADRs (exl), the returns are negative and first-order correlated. The conditional volatility processes are stationary for both two Chinese ADRs portfolios: $\hat{\alpha}_{ADR} + \hat{\beta}_{ADR} \leq 1$.

In the estimation for Chinese ADRs (inc), the coefficient of lagged US (host market) and Shanghai (local market) returns are statistically insignificant. The Chinese ADRs (inc) only experience the mean spillover effect from Hong Kong (underlying market), with the coefficient equal to 0.153. On the other side, the lagged Hong Kong (underlying market) returns and the contemporary residuals of US, Hong Kong and Shanghai are dramatically significant in explaining the current Chinese ADRs (inc). Hence, there is strong evidence of volatility spillover from US, Hong Kong and Shanghai to Chinese ADRs (inc), i.e. $\hat{\phi}_{ADR}$, $\hat{\psi}_{ADR}$ and $\hat{\zeta}_{ADR}$ are significantly positive. Among them, Hong Kong (underlying market) has the biggest volatility spillover effect with the coefficient: $\hat{\psi}_{ADR}=1.214$, that is to say, the Chinese ADRs (inc) fully absorbs the fluctuation in Hong Kong market, i.e. $\hat{\psi}_{ADR}=1.214>1$. Followed is US (host market), which has the subordinate volatility spillover on Chinese ADRs (inc), i.e. $\hat{\phi}_{ADR}=1.054$. Shanghai (local market) has the least spillover effect on Chinese ADRs (inc), as the coefficient is merely 0.0046.

Regarding the Chinese ADRs (exl), the coefficient of lagged US (host market), Hong Kong (underlying market), and Shanghai (local market) returns are statistically insignificant. Thus, no mean spillover effect is observed from US, Hong Kong and Shanghai to Chinese ADRs (exl). In contrast, all of the contemporary residuals of US, Hong Kong and Shanghai are statistically significant in explaining the current Chinese ADRs (exl). Hence, there is strong evidence of volatility spillover from US, Hong Kong and Shanghai to Chinese ADRs (exl), i.e. $\hat{\phi}_{ADR}$, $\hat{\psi}_{ADR}$ and $\hat{\zeta}_{ADR}$ are significantly positive. Among them, Hong Kong (underlying market) has the biggest volatility spillover effect with the coefficient: $\hat{\psi}_{ADR}=0.833$, followed is US (host market), which has the subordinate volatility spillover on Chinese ADRs (exl), i.e. $\hat{\phi}_{ADR}=0.802$, while Shanghai (local market) has the least spillover effect on Chinese ADRs (exl), i.e. $\hat{\zeta}_{ADR}=0.110$.

Comparably, both Chinese ADRs (inc) and Chinese ADRs (exl) experience volatility spillover effect from US (host market), Hong Kong (underlying market) and Shanghai (local market). They follow the same rank of volatility spillover effect, Hong Kong (underlying market) > US (host market) > Shanghai (local market). Nevertheless, the weight of volatility spillover effect of US and Hong Kong on

Chinese ADRs (inc) is larger than Chinese ADRs (exl), decreasing by 23% and 31% respectively. This can be attributed to the effect of China Mobile Ltd. whose volatility spillover is strongly influenced by US and Hong Kong market rather than Shanghai market. Correspondingly, the coefficient of Shanghai volatility spillover dramatically rises by 139 % for Chinese ADRs (exl). Moreover, the mean spillover effect in Chinese ADRs (inc) is different from Chinese ADRs (exl), in that Chinese ADRs (inc) owns mean spillover effect from Hong Kong (underlying market) whilst there is no mean spillover effect on Chinese ADRs (exl). These results conform our initial hypotheses that there, indeed, exist a change in spillover effect driven by China Mobile Ltd..

Table 5: Estimated coefficients for the symmetric unconditional spillover model in the full sample period (Jan 2002 to Sep 2007)

	c_0	c_1	γ	δ	φ	ϕ	ψ	ζ	ω	α	β
US	0.0004 (0.0297)	-0.0724 (0.0132)							9.72E-07 (0.0000)	0.0556 (0.0000)	0.9320 (0.0000)
HK	0.0005 (0.0130)	-0.0110 (0.6553)	0.4440 (0.0000)			0.1571 (0.0000)			1.20E-06 (0.0096)	0.0349 (0.0000)	0.9462 (0.0000)
SH	0.0004 (0.1875)	-0.0064 (0.8087)	0.0479 (0.1686)	0.0451 (0.1538)		0.0160 (0.6257)	0.1848 (0.0000)		4.22E-06 (0.0000)	0.0748 (0.0000)	0.9072 (0.0000)
ADR (inc)	0.0016 (0.0000)	-0.1805 (0.0000)	0.0379 (0.3022)	0.1533 (0.0000)	-0.0017 (0.9241)	1.0543 (0.0000)	1.2143 (0.0000)	0.0463 (0.0149)	2.53E-06 (0.0001)	0.0369 (0.0000)	0.9452 (0.0000)
ADR (exl)	0.0015 (0.0000)	-0.1148 (0.0000)	-0.0018 (0.9560)	0.0435 (0.2234)	0.0354 (0.0773)	0.8015 (0.0000)	0.8328 (0.0000)	0.1104 (0.0000)	3.25E-06 (0.0000)	0.0665 (0.0000)	0.9150 (0.0000)

Note: P-values are in parentheses at the level of significance of 5%.

Table 6: Joint Wald tests for the following null hypotheses regarding the spillover effects in the constant spillover effect model in the full sample period (Jan 2002 to Sep 2007)

	Wald ₁	Wald ₂	Wald ₃	Wald ₄	Wald ₅
ADRs (inc)	1351.789 (0.0000)	1491.617 (0.0000)	5.929 (0.0516)	17.535 (0.0005)	2840.430 (0.0000)
ADRs (exl)	990.129 (0.0000)	836.556 (0.0000)	45.975 (0.0000)	4.960 (0.1747)	1966.034 (0.0000)

Note:

$H_0^1: \gamma_{ADR} = \phi_{ADR} = 0$ (no US spillover effects)

$H_0^2: \delta_{ADR} = \psi_{ADR} = 0$ (no Hong Kong spillover effects)

$H_0^3: \varphi_{ADR} = \varsigma_{ADR} = 0$ (no Shanghai spillover effects)

$H_0^4: \gamma_{ADR} = \delta_{ADR} = \varphi_{ADR} = 0$ (no mean spillover effects)

$H_0^5: \phi_{ADR} = \psi_{ADR} = \varsigma_{ADR} = 0$ (no volatility spillover effects)

Under the null hypotheses Wald₁, Wald₂, Wald₃, Wald₄, and Wald₅ are $\chi^2(2)$ distributed. P-values are in parentheses at the 5% level of significance.

Table 6 provides the robust Wald test for five different joint hypotheses in terms of spillover effects.

For Chinese ADRs (inc), the US mean spillover parameter, $\hat{\gamma}_{ADR}$, is positive and insignificant which indicates no US mean spillover effect. While there is strong evidence of US volatility spillover effect, i.e. $\hat{\phi}_{ADR}$ is positive and significant at the 5% significance level. Thus, the null hypothesis of robust Wald test that there is no US spillover effects, $H_0^1: \gamma_{ADR} = \phi_{ADR} = 0$ is jointly rejected at the 5% level of significance. Strong evidence of both the Hong Kong mean spillover and the Hong Kong volatility spillover can be found, i.e. $\hat{\delta}_{ADR}$ and $\hat{\psi}_{ADR}$ are positive and significant at the 5% level of significance. The null hypothesis of robust joint Wald test that there are no Hong Kong spillover effects $H_0^2: \delta_{ADR} = \psi_{ADR} = 0$ is strongly rejected at the 5% level of significance. There is strong indication for Shanghai volatility spillover effect in Chinese ADRs (inc), i.e. $\hat{\varsigma}_{ADR}$ is positive and significant at the 5% significance level. In contrast, no Shanghai mean spillover effect is found in Chinese ADRs (inc) at the 5% significance level. The null hypothesis of robust Wald test that there are no Shanghai spillover effects $H_0^3: \varphi_{ADR} = \varsigma_{ADR} = 0$ is jointly rejected at the 5% level of significance. The robust joint Wald test for no mean spillover $H_0^4: \gamma_{ADR} = \delta_{ADR} = \varphi_{ADR} = 0$ and the Wald test for no volatility spillover $H_0^5: \phi_{ADR} = \psi_{ADR} = \varsigma_{ADR} = 0$ are strongly rejected at the 5% significance level, which is consistent with the three individual Wald test above.

For Chinese ADRs (exl), the US mean spillover parameter, $\hat{\gamma}_{ADR}$, is negative and insignificant which indicates no US mean spillover effect. While there is strong evidence of US volatility spillover effect, i.e. $\hat{\phi}_{ADR}$ is positive and significant at the

5% significance level. Thus, the null hypothesis of robust Wald test that there is no US spillover effects , $H_0^1 : \gamma_{ADR} = \phi_{ADR} = 0$ is jointly rejected at the 5% level of significance. This is the same for Hong Kong and Shanghai, i.e. $\hat{\delta}_{ADR}$ and $\hat{\phi}_{ADR}$ are positive and insignificant at the 5% level of significance; $\hat{\psi}_{ADR}$ and $\hat{\zeta}_{ADR}$ are positive and significant. Hence, the null hypothesis of robust joint Wald test that there is no Hong Kong spillover effects, $H_0^2 : \delta_{ADR} = \psi_{ADR} = 0$ and the Wald test that there is no Shanghai spillover effects , $H_0^3 : \phi_{ADR} = \zeta_{ADR} = 0$ are both jointly rejected at the 5% level of significance. In this term, the robust joint Wald test for no mean spillover , $H_0^4 : \gamma_{ADR} = \delta_{ADR} = \phi_{ADR} = 0$ can not be rejected at the 5% significance level. Nevertheless, the joint Wald test for no volatility spillover $H_0^5 : \phi_{ADR} = \psi_{ADR} = \zeta_{ADR} = 0$ is strongly rejected at the 5% significance level. These results are consistent with three individual Wald test above.

To sum up, the results from both forms of ADRs (Table 5 and Table 6) indicate significant volatility spillover effects between Chinese ADRs at NYSE and their host (US), underlying (Hong Kong) and local (Shanghai) markets, with the biggest impact coming from the underlying market (Hong Kong), followed by host market (US), whereas the local market (Shanghai) seems to have weak influence. In terms of the mean of ADRs returns, none of US, Hong Kong and Shanghai markets has the mean spillover effects for Chinese ADRs (exl); while Chinese ADRs (inc) are found to experience the mean spillover effect from their underlying market (Hong Kong). This noteworthy change between Chinese ADRs (inc) and Chinese ADRs (exl) is probably due to the stronger market relationship between China Mobile Ltd. and its underlying market in Hong Kong.

5.2. Conditional Correlation

5.2.1. Correlation

We examine the conditional correlation of Chinese ADRs portfolio listed at NYSE with US, Hong Kong and Shanghai markets. The results are reported in Table 7, Table

8, Figure A3 and Figure A4 for Chinese ADRs (inc) and Chinese ADRs (exl), respectively.

For Chinese ADRs (inc), US and Hong Kong have the average correlation exceeding 40% with Chinese ADRs (inc), comparing with Shanghai whose average correlation is lower than 15%. Moreover, Figure A3 exhibits the time series evolution of the conditional correlation between unexpected returns for ADRs (inc) and unexpected returns from three markets. Results show that Chinese ADRs (inc) are highly integrated with the US (host market) and Hong Kong (underlying market), especially Hong Kong market (underlying market), that correlation remain stable around the mean of 0.664.

Regarding Chinese ADRs (exl), the inferences are very similar to Chinese ADRs (exl) in Table 8 and Figure A4. We still observe that the average correlation between US (host market), Hong Kong (underlying market) and ADRs (exl) are over 40% as well, following the same tendency around the mean of 0.432 and 0.533, respectively. However, the correlation between Shanghai (local market) and ADRs (exl) increases to above 15% in this case, comparing with Chinese ADRs (inc).

Overall, high correlation is observed between US (host market), Hong Kong (underlying market) and Chinese ADRs in both cases, while the local market (Shanghai) exhibits lower correlation with Chinese ADRs. It maybe interesting to note that the correlations between US, Hong Kong and ADRs portfolio decrease from 0.489 to 0.432 and from 0.664 to 0.533, respectively. This supports our statement previously that China Mobile Ltd. which is excluded from ADRs (inc) is higher related to US (host market) and Hong Kong (underlying market) than other ten ADRs. (See Table 5 and Table 6)

Table 7: Conditional Correlation between unexpected returns for ADRs (inc) in the full sample period (Jan 2002 to Sep 2007)

Corr	US	Hong Kong	Shanghai
Mean	0.489	0.664	0.116
Stdev	0.107	0.038	0.016
Min	0.248	0.508	0.081
Max	0.799	0.797	0.186

Table 8: Conditional Correlation between unexpected returns for ADRs (exl) in the full sample period (Jan 2002 to Sep 2007)

Corr	US	Hong Kong	Shanghai
Mean	0.432	0.533	0.162
Stdev	0.116	0.074	0.028
Min	0.146	0.227	0.070
Max	0.788	0.806	0.262

5.2.2. Variance Ratios

So far, we have only discussed the sign and significance of the spillover parameters. In order to evaluate the quantitative significance of the US, Hong Kong and Shanghai volatility spillover effects on the variance of the unexpected returns of Chinese ADRs portfolio, the variance ratios $VR_{ADR,t}^{US}$, $VR_{ADR,t}^{HK}$, $VR_{ADR,t}^{SH}$ and $VR_{ADR,t}^{ADR}$ from equations (24) to (27) are calculated. Table 9 and Table 10 reports the mean and standard deviations of the variance ratios for Chinese ADRs (inc) and Chinese ADRs (exl), respectively.

On average, the US volatility spillover effects account for 25% of the conditional variance of the unexpected returns of Chinese ADRs (inc). It is remarkably that the Hong Kong volatility spillover effects are particularly strong, making up for 35.38% of the conditional variance of the unexpected returns of Chinese ADRs (inc). Whereas, rather weak volatility spillover effects is observed from Shanghai to Chinese ADRs (inc) (mean of 0.14% only). Finally, the pure local volatility effects are substantial in Chinese ADRs (inc) (mean of 39.39%). Generally, the volatility spillover Chinese ADRs (inc) is highly influenced by Hong Kong and their own, which share the similar weight in variance of unexpected returns of Chinese ADRs (inc), followed by US.

Figure A5 exhibits the time series evolution of the variance ratios for Chinese ADRs (inc). The Hong Kong variance ratio and its own variance ratio follow the similar path. They happen a sharp fall in the mid-2002, and then return back and fluctuate around the mean of 35%, afterwards. Contrary, for US, it has a significant jump in the mid-2002, and decreases at a relatively stable rate in the following years. The variance ratio of Shanghai seems to be negligible over time. Consistent with the previous analysis, the Hong Kong variance ratio is the biggest, followed by US, and Shanghai e.g. $VR_{ADR,t}^{HK}=35.38\%$, $VR_{ADR,t}^{US}=25\%$, $VR_{ADR,t}^{SH}=0.14\%$.

Regarding Chinese ADRs (exl), the mean of Hong Kong and US variance ratios amount to 22.5% and 20%, respectively, implying considerably high influence for the variance of unexpected returns of Chinese ADRs (exl). Whereas, the variance of Chinese ADRs (exl) unexpected returns is least affected by Shanghai volatility effect; $VR_{ADR,t}^{SH}=1.1\%$. It is found that the major volatility effect of Chinese ADRs (exl) comes from its own local volatility, i.e. $VR_{ADR,t}^{ADR}=56.4\%$.

Figure A6 presents the time varying variance ratios for Chinese ADRs (exl) as well. The variance ratio of pure local volatility effect is observed to be substantial in Chinese ADRs (exl), (mean of 56.4%). Following are Hong Kong and US, which take up 22.5% and 20%, respectively. It is remarkable, that the portion of local Chinese ADRs (exl) spillover overtakes the US and Hong Kong spillover in the Chinese ADRs (exl) after the end of 2002. But the rank of spillover effect remain the same, that Hong Kong > US > Shanghai, where the variance ratio of Shanghai is fairly weak.

Summing up, the US and Hong Kong variances are strong important to the variance of the unexpected returns of two cases of Chinese ADRs, whereas, very weak volatility spillover effect from Shanghai is observed in the variance ratio. The volatility spillover effect from Hong Kong is superior to that of US for Chinese ADRs (inc), whilst, in Chinese ADRs (exl), Hong Kong and US makes no big difference in the volatility spillover effects.

Table 9: Variance Ratios in Constant Spillover Model (ADRs inc)

	VR(US)	VR(HK)	VR(SH)	VR(ADRs inc)
Mean	0.250	0.354	0.001	0.394
Stdev.	0.114	0.066	0.001	0.089
Min	0.062	0.158	0.000	0.118
Max	0.638	0.585	0.008	0.666

Table 10: Variance Ratios in Constant Spillover Model (ADRs exl)

	VR(US)	VR(HK)	VR(SH)	VR(ADRs exl)
Mean	0.200	0.225	0.011	0.564
Stdev.	0.110	0.068	0.008	0.128
Min	0.021	0.045	0.002	0.198
Max	0.621	0.601	0.058	0.931

5.3. Asymmetric Spillover Model

This part investigates the existence of the asymmetries in Chinese ADRs portfolio listed at NYSE to upturns (positive one-period lagged returns) and downturns (negative one-period lagged returns) as well as the positive shocks (positive contemporary residuals) and negative shocks (negative contemporary residuals) in the US, Hong Kong and Shanghai markets.

The result is provided in Table 11 for Chinese ADRs (inc) and Chinese ADRs (exl) in the full sample period. The corresponding Wald tests for six hypotheses regarding asymmetric responses are presented in Table 12.

In case of Chinese ADRs (inc), we find the coefficients for $R_{HK,t-1}^+$ and $R_{HK,t-1}^-$ are strongly significant. The size for positive and negative lagged return of Hong Kong i.e. $\delta_{1,ADR}$ (0.161) and $\delta_{2,ADR}$ (0.141) are almost the same. This suggests that an increase or decrease in Hong Kong market has the same impact on Chinese ADRs (inc). The Wald test for null hypothesis of no asymmetry to Hong Kong lagged returns: $H_0^2: \delta_1 = \delta_2$. The symmetric responds to the lagged returns of US and Shanghai markets are also found, namely, the coefficients $\gamma_{1,ADR}$ and $\gamma_{2,ADR}$, $\phi_{1,ADR}$ and $\phi_{2,ADR}$ are insignificant and close to each other. They are consistent with the Wald tests of no asymmetries to US and Shanghai lagged returns: $H_0^1: \gamma_1 = \gamma_2$ and $H_0^3: \phi_1 = \phi_2$. There is evidence of symmetric response to the US contemporary shocks: the coefficient of $e_{US,t}^+$, namely, ϕ_1 (1.098) and the coefficient of $e_{US,t}^-$, namely, ϕ_2 (1.037) are significant with close size. The similar conclusion can be obtained regarding the impacts of the Hong Kong contemporary shocks on Chinese ADRs (inc), as the coefficient of $e_{HK,t}^+$, namely, ψ_1 (1.141) is not distinct from the coefficient of $e_{HK,t}^-$, namely, ψ_2 (1.203). Hence, what the investors in Chinese ADRs (inc) reward from the positive shocks ($e_{US,t}^+$ and $e_{HK,t}^+$) is equal to what they get lost from the negative shocks ($e_{US,t}^-$ and $e_{HK,t}^-$) in US and Hong Kong markets. The Wald tests for null hypotheses of no asymmetries to the US and Hong Kong residuals: $H_0^4: \phi_1 = \phi_2$ and $H_0^5: \psi_1 = \psi_2$ give the unchanged conclusions: both null hypotheses are not rejected. An interesting result is discovered in the response to Shanghai contemporary

shocks: $e_{SH,t}$, the coefficient of $e_{SH,t}^-$, namely, ς_2 (p-value 0.012) is significant while the coefficient of $e_{SH,t}^+$, namely, ς_1 (p-value 0.722) is insignificant. Both of them are trivial in affecting the returns of Chinese ADRs (inc) and close to each other. This implies that the investor only react to the negative shock of Shanghai with relatively negligible loss. The Wald test of the null hypothesis: $H_0^6 : \varsigma_1 = \varsigma_2$ leads to the result of no asymmetry to the shocks of Shanghai.

The inference is the same except that, neither positive one-period lagged Hong Kong return nor the negative one-period lagged Hong Kong return is capable of explaining the returns in the Chinese ADRs (exl). All the Wald tests of the null hypotheses: $H_0^1 : \gamma_1 = \gamma_2$, $H_0^2 : \delta_1 = \delta_2$, $H_0^3 : \varphi_1 = \varphi_2$, $H_0^4 : \phi_1 = \phi_2$, $H_0^5 : \psi_1 = \psi_2$ and $H_0^6 : \varsigma_1 = \varsigma_2$ come to the same conclusion of no asymmetries as above.

To summarize, indicated by the Wald tests, we can conclude that the symmetric reactions in Chinese ADRs to the upturns (positive one-period lagged returns) and downturns (negative one-period lagged returns) as well as the positive shocks (positive contemporary residuals) and negative shocks (negative contemporary residuals) from the US, Hong Kong and Shanghai markets. This suggests that the Chinese ADRs responds no difference to the upturns and downturns as well as the positive and negative shocks.

Table 11: Estimated coefficients for the asymmetric unconditional spillover model during the whole sample period (Jan 2002 to Sep 2007)

	C_0	C_1	γ_1	γ_2	δ_1	δ_2	φ_1	φ_2	ϕ_1	ϕ_2	ψ_1	ψ_2	ς_1	ς_2
ADRs (inc)	0.002 (0.001)	-0.197 (0.000)	0.022 (0.647)	0.036 (0.497)	0.161 (0.000)	0.141 (0.004)	-0.017 (0.537)	-0.003 (0.932)	1.098 (0.000)	1.037 (0.000)	1.141 (0.000)	1.203 (0.000)	-0.013 (0.722)	0.092 (0.012)
ADRs (exl)	0.003 (0.001)	-0.121 (0.000)	-0.033 (0.506)	0.049 (0.381)	0.029 (0.533)	0.029 (0.570)	0.035 (0.241)	0.007 (0.850)	0.814 (0.000)	0.865 (0.000)	0.898 (0.000)	0.945 (0.000)	0.045 (0.248)	0.119 (0.003)

Note: p-values are in the parentheses at the 5% level of significance.

Table 12: Joint Wald tests for the following null hypotheses regarding the spillover effects in the constant spillover model with the whole sample

	Wald ₁	Wald ₂	Wald ₃	Wald ₄	Wald ₅	Wald ₆
ADRs (inc)	0.049 (0.824)	0.108 (0.742)	0.096 (0.757)	0.485 (0.486)	0.488 (0.485)	3.264 (0.071)
ADRs (exl)	1.383 (0.239)	6.29E-06 (0.998)	0.325 (0.569)	0.281 (0.596)	0.235 (0.628)	1.356 (0.244)

Notes:

$H_0^1 : \gamma_1 = \gamma_2$ (no asymmetries to US lagged returns)

$H_0^2 : \delta_1 = \delta_2$ (no asymmetries to Hong Kong lagged returns)

$H_0^3 : \varphi_1 = \varphi_2$ (no asymmetries to Shanghai lagged returns)

$H_0^4 : \phi_1 = \phi_2$ (no asymmetries to US shocks)

$H_0^5 : \psi_1 = \psi_2$ (no asymmetries to Hong Kong shocks)

$H_0^6 : \zeta_1 = \zeta_2$ (no asymmetries to Shanghai shocks)

Under the null hypotheses Wald₁, Wald₂, Wald₃, Wald₄, Wald₅ and Wald₆ are $\chi^2(2)$ distributed. P-values are in the parentheses at the 5% level of significance.

6. Conclusion

In this paper, we have investigated how the returns and volatility of Chinese ADRs listed at NYSE are affected by their host market (US), underlying market (Hong Kong) and local market (Shanghai) by means of GARCH model. Eleven Chinese ADRs which were issued at NYSE before 2002 are selected to our sample. We divide the eleven Chinese ADRs into two groups by employing China Mobile Ltd. as the benchmark: the portfolio denoted Chinese ADRs (inc) includes all eleven ADRs, and the portfolio denote Chinese ADRs (exl) excludes China Mobile Ltd..

Our results provided by correlation matrix, constant spillover model and Wald tests, reveal that the host, underlying and local markets are correlated with ADRs and they all turned out to have spillover effects on Chinese ADRs, and the relative importance follows the rank: underlying market (Hong Kong) > host market (US) > local market (Shanghai). This is consistent with our hypothesis I. Specifically, Chinese ADRs experience significant volatility spillover from their underlying, host and local markets. This suggests that the returns of Chinese ADRs have significant risk exposure to host market index (US), underlying market index (Hong Kong) and local

market index (Shanghai). In terms of conditional returns of Chinese ADRs, no mean spillover effect is found in Chinese ADRs (exl), whereas the underlying market (Hong Kong) is found to have significant impact on the returns of Chinese ADRs (inc). Besides, it is of interest to note the difference of the volatility spillover between Chinese ADRs (inc) and Chinese ADRs (exl), which is reflected in variance ratios for the three individual markets. The weight of volatility spillover of Hong Kong and US in explaining the variance of unexpected returns of Chinese ADRs (exl) decrease, compared to Chinese ADRs (inc). This maybe attribute to the dominating role of China Mobile Ltd. which has a close connection with Hong Kong market. An additional finding is the existence of the symmetries in Chinese ADRs to upturns and downturns as well as the positive shocks and negative shocks in the US, Hong Kong and Shanghai markets.

Only some of our findings are consistent with the results of Chen, Chou, Yang (2002) and Kutan and Zhou (2006) who found that the most influential factor in ADRs is their underlying markets. The majority of our results are opposite to the following previous studies: Jiang (1998), Choi and Kim (2000) and Kutan and Zhou (2006), who discovered the returns of underlying, host and local markets are all important in explaining the variation of ADRs returns, but ADRs return are not exposed to US shocks; Alaganar and Bhar (2001), who found that ADRs have a low correlation with US market. This is mainly due to the difference in our methodology and sample period, because China entering to WTO (Dec 2001) has increased its degree of integration and trade frequency with the world market, which, furthermore, leads to a greater impact from US stock market on Chinese ADRs.

Based on our findings, Chinese ADRs are probably not providing great diversification benefits for US investors. This is consistent with our hypothesis II. The correlation between host markets (US) and Chinese ADRs infers that it is not bad to diversify. However, further analysis from our constant spillover model makes us doubt about its feasibility. US shocks have significant impact on the conditional volatility (risk) of Chinese ADRs, which implies that Chinese ADRs would move in the same direction as US stocks. These results probably indicate that US investors should be prudent in considering a diversification strategy. This is also contradictory to Jiang (1998), Choi and Kim (2000) and Kutan and Zhou (2006), who all suggest ADRs as an international diversification vehicle for US investors.

As an initial attempt in exploring the spillover effect of Chinese ADRs using GARCH model and the latest ADRs data, the paper has also other interesting findings. Why does the Shanghai market has relatively limited impact on Chinese ADRs whose mother companies are mainly set up in Mainland China? Will the spillover effects from the US market overtake Hong Kong market when stock markets become more integrated? It may be worthwhile to pursue more rigorous research into these questions.

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Appendix

Table A: Chinese ADRs Listed at NYSE (up to 30 October 2007)

Name	Ticker	Ratio	Industry sector	Underlying ADR	Effective date
Sinopec Shanghai Petrochemical Co.Ltd.	SHI	1 : 100	Chemicals	HK 0338	July 1993
Huaneng Power International Inc.	HNP	1 : 40	Electric utility	HK 0902	October 1994
Guangshen Railway Co.Ltd.	GSH	1 : 50	Transportation	HK 0525	May 1996
China Eastern Airlines Corp.Ltd.	CEA	1 : 100	Airlines	HK 0670	February 1997
China Southern Airlines Co.Ltd.	ZNH	1 : 50	Airlines	HK 1055	July 1997
China Mobile Ltd.	CHL	1 : 5	Telecommunications	HK 0941	October 1997
Yanzhou Coal Mining Co.Ltd.	YZC	1 : 50	Mining	HK 1171	March 1998
Petrochina Co.Ltd.	PTR	1 : 100	Oil and gas	HK 0857	April 2000
China Unicom Ltd.	CHU	1 : 10	Telecommunications	HK 0762	June 2000
China Petroleum&Chemical Corp.	SNP	1 : 100	Oil and gas	HK 0386	October 2000
Aluminum Corp. of China Ltd.	ACH	1 : 25	Mining	HK 2600	December 2001
China Telecom Corp.Ltd.	CHA	1 : 100	Telecommunications	HK 0728	November 2002
China Life Insurance	LFC	1 : 15	Insurance	HK 2628	December 2003
Semiconductor Manufacturing International Corp	SMI	1 : 50	Semiconductors	HK 0981	March 2004
China Netcom Group Corporation(Hong Kong) Limited	CN	1 : 20	Fixed Line Telecommunications	HK 0906	November 2004
Suntech Power Holdings Co Ltd.	STP	1 : 1	Utility Gas/electricity	US	December 2005
Mindray Medical International Ltd.	MR	1 : 1	Health care/Medical device	US	September 2006

New Oriental Education&Technology Group Inc.	EDU	1 : 4	Specialized Consumer Services	US	September 2006
Trina Solar Limited	TSL	1 : 100	Electrical Components&Equipment	US	December 2006
Tongjitang Chinese Medicines Company	TCM	1 : 4	Pharmaceuticals	US	March 2007
Sincere Pharmaceutical Group	SCR	1 : 2	Pharmaceuticals	US	April 2007
Acorn International.Inc.	ATV	1 : 3	Broadline Retailers	US	May 2007
LDK Solar Co.,Ltd.	LDK	1 : 1	Electrical Components&Equipment	US	June 2007
Yingli Green Energy Holding Company Limited	YGE	1 : 1	Electrical Components&Equipment	US	June 2007
WuXi Pharma Tech Inc	WX	1 : 8	Pharmaceuticals	US	August 2007
E-House Holdings Limited	EJ	1 : 1	Real Estate Holding&Development	US	August 2007
China Digital TV Holding Co.,Ltd.	STV	1 : 1	Electronics	US	October 2007
Longtop Financial Technologies Limited	LFT	1 : 1	Computer Services	US	October 2007
Noah Education Holdings,Ltd.	NED	1 : 1	Specialized Consumer Services	US	October 2007

Figure A1 – A6

Figure A1: Indices (from Jan 2002 to Sep 2007)

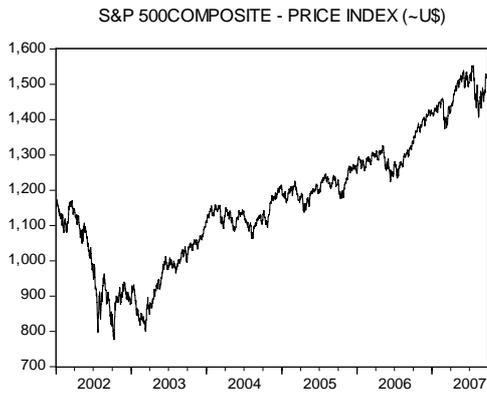


Figure A2: Squared return (from Jan 2002 to Sep 2007)

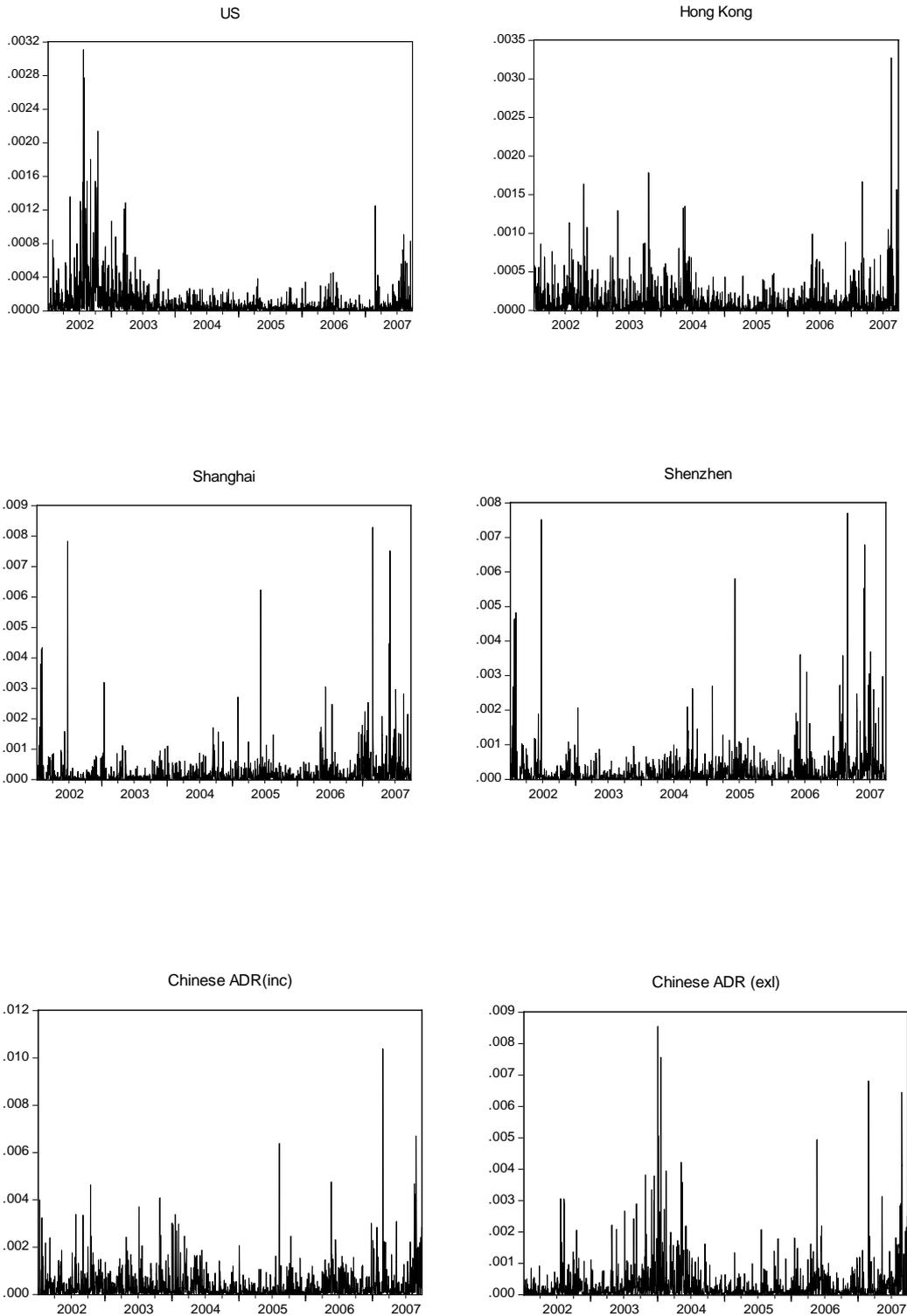


Figure A3: Conditional Correlation between unexpected returns for ADRs (inc) in the full sample period (Jan 2002 to Sep 2007)

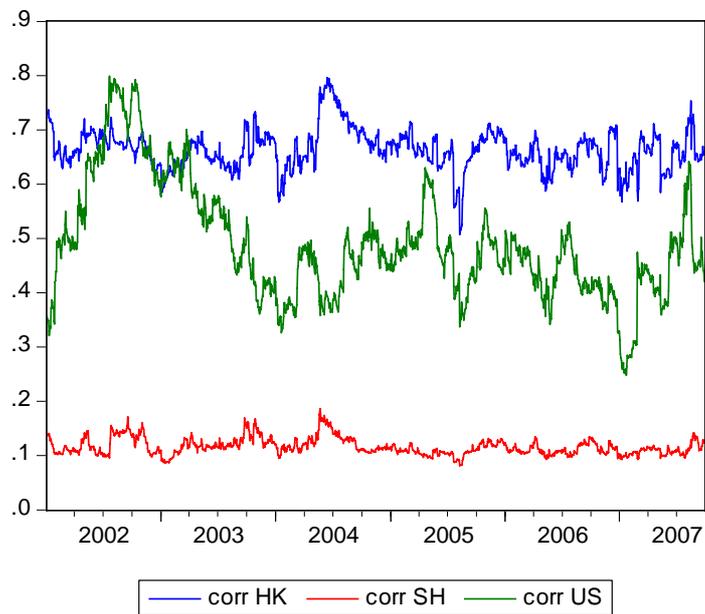


Figure A4: Conditional Correlation between unexpected returns for ADRs (exl) in the full sample period (Jan 2002 to Sep 2007)

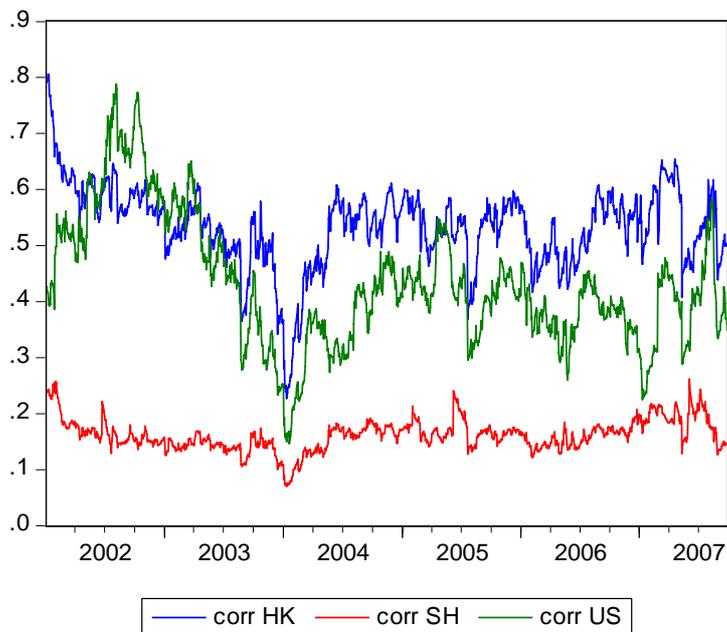


Figure A5: Variance Ratio of Chinese ADRs (inc)

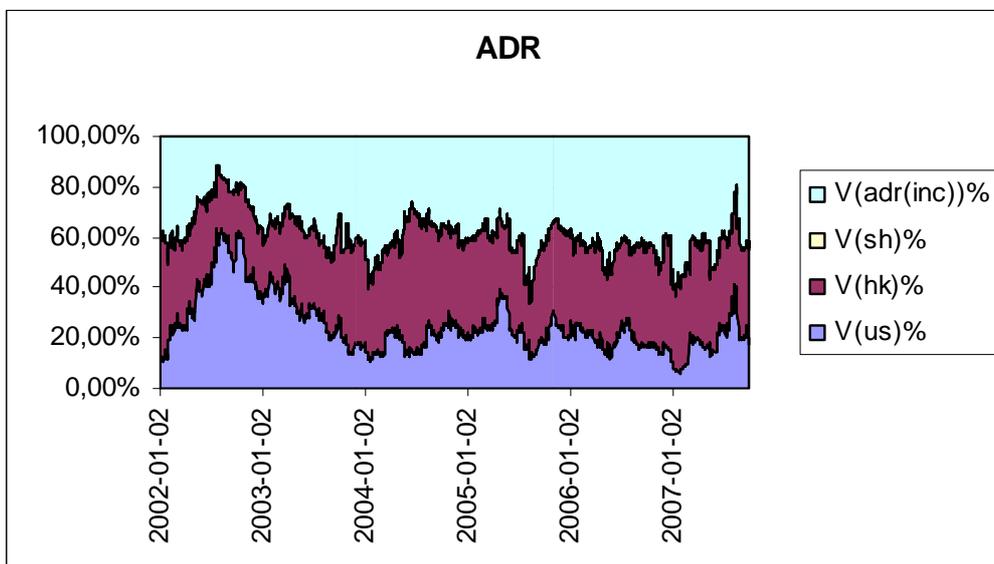
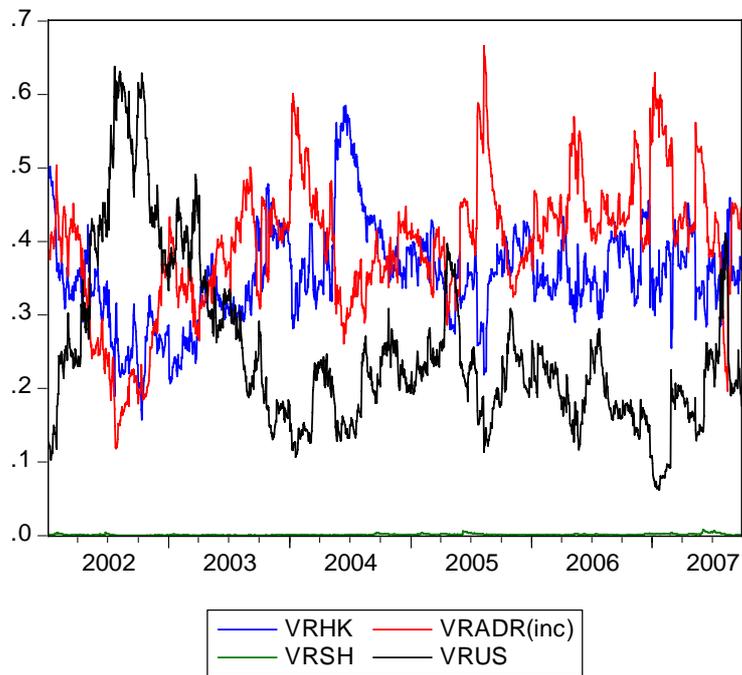


Figure A6: Variance Ratio of Chinese ADRs (exl)

