Are there spillover effects from Hong Kong and the United States to Chinese stock markets?

Katharina Diekmann*

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Institute of Empirical Economic Research
University of Osnabrück
Rolandstrasse 8
49069 Osnabrück
Germany

*e-mail: katharina.diekmann@uni-osnabrueck.de, phone: +49 (0)541 969 3518, fax: +49 (0)541 969 2757.

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Abstract: Stock market integration of mainland China is analyzed before and after the liberalization of Chinese stock exchange segments. We apply a causality-in-variance procedure, using four mainland China stock market indices, two indices of the stock exchange in Hong Kong and the Dow Jones Industrial index. We find evidence of global and regional integration, but we do not find evidence for increasing integration after stock market liberalization, neither with Hong Kong nor with the United States.

Keywords: Chinese Stock Market Integration, Spillover Effects, Causality-in-Variance

JEL: C23, G10, G15

1 Motivation

Spillover effects from stock markets in Hong Kong and the United States to the two emerging stock exchanges in mainland China - Shanghai and Shenzhen - are empirically analyzed in this paper. The implementation of the Qualified Foreign Institutional Investor (QFII) program on 1 December 2002 offers the opportunity to address the question whether these liberalization has lead to increased integration. Therefore, we study the interdependencies among stock markets in mean returns and volatility to determine the transfer mechanism of information within the Chinese stock markets and the stock markets in Hong Kong and the United States.

In general, integration links of stock markets and the effects of liberalization and deregulation on stock market comovements in developed and emerging markets has experienced much interest. Particularly China has attracted much research for different reasons. Its high growth rates, ongoing liberalization reforms[1] and the important feature that listed companies are allowed to issue different types of equity shares offer a special research environment to address several questions about integration and relation properties.

In our research, we concentrate on A shares which were initially designed for domestic investors, B shares which were restricted to foreign investors and H shares which are issued in Hong Kong and which can be traded by all investors except for Chinese residents.[2] With the implementation of the QFII program, the A and B share segments are no longer completely separated as it allows foreign institutional investors to purchase and trade A shares.[3]

With regard to the existing literature, the main novelty in our study is the application of the two-stage Lagrange multiplier procedure proposed by Cheung and Ng (1996) on appropriate ARMA(l,m)-GARCH(1,p)-M (Engle (1982), Bollerslev (1986), Engle et al. (1987)) estimations of our stock market indices. Four-year samples before and after the implementation of the QFII program are used to determine Chinese' stock market integration to regional and global markets. GARCH-M models allow - beside the consideration of different volatility patterns over time - for possible interactions within conditional mean and conditional variance of

[1] In addition to the deregulation reforms due to the QFII program, the B share markets were opened for domestic investors in February 2001. In 2006, a counterpart of the QFII, the Qualified Domestic Institutional Investor (QDII) program was established allowing Chinese institutional investors to trade shares abroad.

[2] In June 1993, China and Hong Kong signed the Chinese-Hong Kong Memorandum of Regulatory Cooperation allowing Chinese enterprises to list their shares (called H shares) on the stock exchange of Hong Kong.

[3] For detailed information about the conditions and restrictions which qualified foreign institutional investors are subject to, see Prasad and Wei (2005). In August 2010, 86 overseas investors had been gained QFII status.

returns of (financial) time series. The univariate time series are estimated in the first step. In the second step, the resulting squared residuals standardized by the conditional variance are used to generate cross correlations and to test the null hypothesis of no causality-in-variance. Causality-in-variance explores the conditional volatility dependencies between two variables and is often used to reveal the transmission between and the assimilation of news (shocks) in stock markets.

Overall, we do not find evidence that this institutional change had an effect on the time series comovements among these markets as the implementation of the QFII program does not cause increasing spillovers in our analysis. While we are able to report causality-in-mean and causality-in-variance in both subsamples, we do not find increased causal links in the post-liberalization phase. This suggests that the implementation of the QFII program neither advances the stock market integration of mainland China to Hong Kong and the United States, nor effectively reduces trading barriers for foreign institutional investors.

This paper is organized as follows: Section 2 describes the data and the unit root properties. In Section 3, the ARMA(l,m)-GARCH(1,p)-M adjustments and estimations are displayed. Section 4 describes the methodology to test for causality and presents the empirical results. Section 5 gives a brief overview of the literature and section 6 concludes.

2 Related Literature

Much research has been done concerning the linkage between stock markets. On the one hand *developed* stock exchanges are examined, reporting in general a leading role of the United States as for instance by Hamao et al. (1990) who analyzed short-run interdependences of Japan, U.K. and the U.S. and Heimonen (2002) who investigates price integration and return convergence for the U.S., U.K., Germany, Japan and Finland and Liu et al. (1998) who furthermore indicate that the degree of interdependence has increased after the stock market crash in 1987.

On the other hand *emerging* markets have triggered much research. The study of Kim and Singal (2000) which examined the monthly data of 18 emerging markets supports the positive effect of stock market liberalization as it leads to more efficient stock markets. Dates of liberalization are often identified and pre- and post-liberalization samples are analyzed. Kim and Singal (2000) for instance estimate changes in level and in volatility of stock returns, inflation, and exchange rates around market openings for 18 emerging markets indicating increasing efficiency.

Other studies use different country samples of *developed* and *emerging* countries analyzing the integration link between them (see for instance Worthington and Higgs (2004) who use Hong Kong, Japan and Singapore as developed markets and Indonesia, Korea, Malaysia, the Philippines, Taiwan and Thailand as emerging markets) or regional indicators calculated from the main regional stock market indices (see for instance Caporale et al. (2006) who use - besides Japan and the U.S. - regional indicators for Asia and Europe.). In general, an increasing level of emerging markets' integration to the rest of the world is indicated.

In the context of stock market integration, Asia and especially China has attracted much research. Johansson and Ljungwall (2009) for instance, analyze short run spillover effects in mean and volatility in the Greater China region (China, Hong Kong and Taiwan) concluding that there are no (direct) spillovers between China and Hong Kong.[4] Using impulse response functions, Phylaktis (1999) reports an increase of market integration of six Pacific Basin countries with Japan and the United States after these countries liberalize their financial markets. Kassimatis (2002) reports decreasing volatility for six emerging markets (Argentina, India, Pakistan, Philippines, South Korea and Taiwan) as response to financial liberalization on the basis of news impact curves in an EGARCH model (Engle and Ng (1993), Nelson (1991)).

Furthermore, several studies deals with the question of domestic integration in China, namely the integration of the A shares (originally designed for domestic investors) and B shares (originally restricted to foreign investors) before and after liberalization efforts (see for instance Kim and Shin (2000), Brooks and Ragunathan (2003) and Wang et al. (2004)).

Ongoing liberalization efforts in China exhibit the opportunity to analyze the effectiveness of these policy reforms in the context of regional and global integration.[5] Lin and Swanson (2008) analyze liberalization reforms in mainland China and the effects on stock markets information transmission. They specify four major reform policies and examine the induced effects on China's stock market integration due to return causality and volatility transmission.

[4] In this study, weekly data of the Hang Seng index, Dow Jones China 88 and Taiwan Weighted index are used. The spillovers are revealed in the framework of VAR-MVEGARCH models where the own past returns and innovations as well as the foreign ones are incorporated.

[5] Some authors examine the changes in the dynamic relationship between stock markets before and in the aftermath of the Southeast Asian crisis, see for instance Caporale et al. (2006).

In their analysis, the opening of the A share market has had the greatest impact on China's integration with global markets. Furthermore, they indicate that the reform policies had only minor impact on regional integration, suggesting that China's stock markets remain segmented from regional markets.

In contrast, Chelley-Steeley (2004) claims, based on a study of four Asian countries which continue to liberalize their financial markets, that regional integration is more prevalent and occurs faster than global integration.[6] Ng (2000) analyze the volatility spillovers from Japan as proxy for regional markets and the U.S. as proxy for the world market to six Pacific-Basin equity markets coming to the results that both markets are important but the world markets influence tends to be greater. Harvey (1995) among others stated that emerging market returns are more influenced by local rather than global information. Beirne et al. (2009) point out that spillovers in mean returns dominate in emerging Asia.

Chui and Kwok (1998) highlight the specific role of Hong Kong in this context. It functions as an intermediary because most of the Chinese news is collected by or funneled through Hong Kong. The paper by Li (2007) confirms this view. In his asymmetric GARCH model he finds evidence of unidirectional volatility spillovers from the Hong Kong stock exchange to the mainland China stock exchanges in Shanghai and Shenzhen.[7] Although he finds no evidence of volatility linkages between the stock exchanges in mainland China and the U.S., he reports that the stock exchanges in Shanghai and Shenzhen are linked with the United States through Hong Kong, which is in turn integrated with the U.S. stock market. Hu et al. (1997) examine the spillover effects of volatility among the two developed stock markets in the United States and Japan and the emerging stock markets in Hong Kong[8], Taiwan, Shanghai and Shenzhen. They find a feedback system between Hong Kong and the U.S. stock market and in addition contemporaneous correlation of the Asian emerging markets with the return volatility of the United States.[9]

[6] Bracker et al. (1999) suggest that the extent of market integration is closely linked with the import dependence structure and the geographical distance between the markets.

[7] However, small coefficients are reported indicating only weak integration.

[8] Note that in the literature, there is no uniform classification of Hong Kong as either developed or emerging market.

[9] Chow and Lawler (2003) also show that there is no evidence of integration between Shanghai and the U.S. market, analyzing the weekly composite indices from these stock markets by a multiple regression approach for the sample period January 1992 to February 2002.

3 Preliminary Data Analysis

To investigate Chinese stock market integration to regional and global markets, Hong Kong is chosen as indicator for regional integration because of its geographical proximity and the close trading ties of Hong Kong with the Chinese economy. Furthermore, the United States are selected because of its' role as important trading partner and capital provider. Hence the United States serve as a good indicator for the integration of China with global markets. Therefore, daily returns - computed as $log(p_t/p_{t-1})$ where p_t is the daily closing price at time t - for the following stock market indices are used: Shanghai Stock Exchange A share index (SHSE A), Shanghai Stock Exchange B share index (SHSE B), Shenzhen Stock Exchange A share index (SZSE A), Shenzhen Stock Exchange B share index (SZSE B), Hang Seng China Enterprises index (H), Hang Seng index (HSI) and the Dow Jones Industrial index (DJI).[10] All data are collected from Thomson Datastream.

Although there are two stock exchanges in mainland China, Chinese enterprises are allowed to list their shares only on one of the two stock markets.[11] Obviously, both exchanges are subject to the same macroeconomic and political decisions, even though dual listing is not permitted.

The whole sample covers the period from 23 November 1998 to 8 December 2006. The sample is divided into a pre- and post-liberalization phase, four years before and after the implementation of the QFII program on 1 December 2002, excluding five trading days before and after this regulatory change.[12]

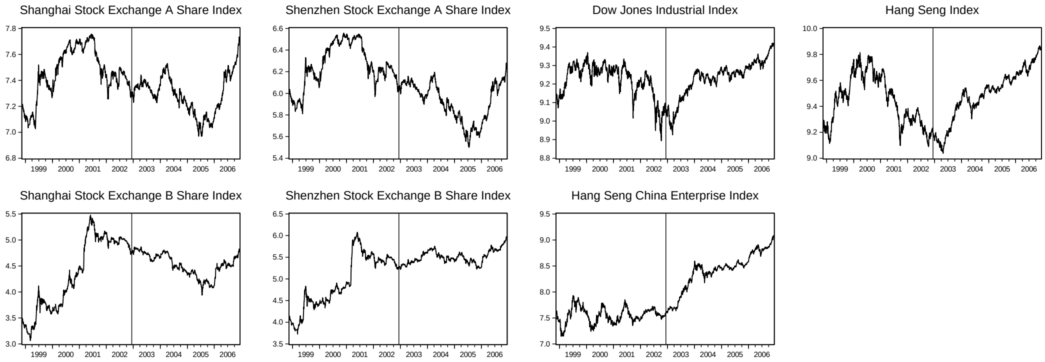
In figures 1 and 2 the data series are shown both in levels and in first differences. The graphs for the Chinese stock exchanges (SHSE A, SHSE B, SZSE A and SZSE B) in figure 1 topped out in late 2001, experienced a lengthy setback until 2005 and rallied until the end of the sample. The DJI and the HSI show some similarities as both hit their lowest levels at the turn of the year 2002/2003 and rallied afterwards, again attaining the peak values of the years 1999/2000 at the end of the sample. The H share index fluctuated around a constant

[10] The currency of A shares is Renminbi, of B shares U.S. dollars on the Shanghai Exchange and Hong Kong dollars on the Shenzhen stock exchange. The H shares' currency is Hong Kong dollars as well as for the Hang Seng index.

[11] In general, those companies which are listed on the Shenzhen Stock Exchange are rather small and export-oriented while those listed on the Shanghai Stock Exchange are often state-owned enterprises.

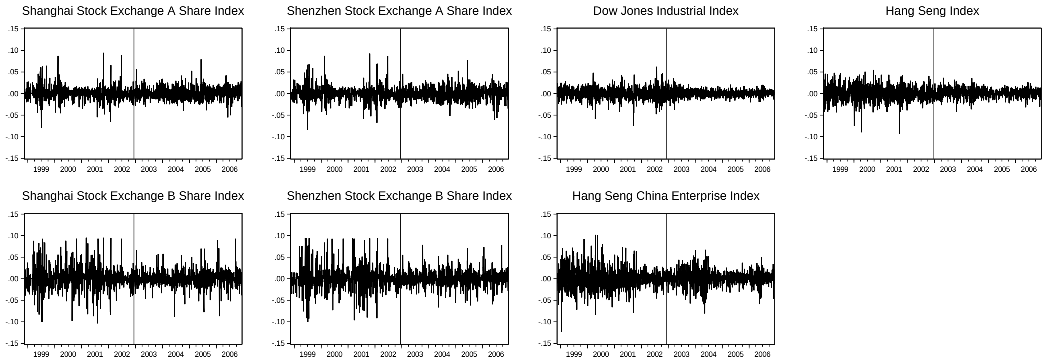
[12] Hence, the pre-liberalization sample is from 23/11/1998 to 22/11/2002 and the post-liberalization from 9/12/2002 to 8/12/2006. In addition, our sample period is unaffected by unusual behavior caused by the Asian financial crisis in 1997.

Figure 1: Log Levels Indices



Note: The graphs for the Shanghai Stock Exchange A share index (SHSE A), Shanghai Stock Exchange B share index (SHSE B), Shenzhen Stock Exchange A share index (SZSE A), Shenzhen Stock Exchange B share index (SZSE B), Dow Jones Industrial index (DJI), Hang Seng index (HSI) and Hang Seng China Enterprise index (H) are displayed. The sample covers the period 23/11/1998 to 08/12/2006.

Figure 2: Stock Market Returns



Note: The graphs for the returns of SHSE A, SHSE B, SZSE A, SZSE B, DJI, HSI and H are displayed. The sample covers the period 23/11/1998 to 08/12/2006.

value until 2003. Afterwards, it experienced strong positive growth with a short-term peak at the end of 2003.[13]

The index return series in figure 2 show that both B share indices are more volatile than their A share counterparts. Furthermore, the DJI is the least volatile one with a decreasing volatility pattern over time. This pattern also applies for the HSI. Particularly at the beginning of the sample, the H share index shows high volatility which becomes somewhat smaller towards the end of the sample.

We start our empirical analysis by testing the unit root properties applying the augmented

[13]The A shares in both markets, Shanghai and Shenzhen, reached a short-term peak after the announcement of the implementation of the QFII program on November 5, 2002. The levels of the peaks are recovered in case of Shanghai in April 2003 and in case of Shenzhen at the end of 2006. Regarding the H share index, it appears that the announcement and implementation of the QFII program leads to stronger growth in comparison to the preceding years. Up to that point, the H share index fluctuated around a constant value.

Table 1: Results of the ADF test

	Levels			Returns			Levels			Returns		
	ADF	k	Prob.	ADF	k	Prob.	ADF	k	Prob.	ADF	k	Prob.
Pre-liberalization							Post-liberalization					
SHSE A	-1.4422	0	0.5626	-31.8979**	0	0.000	0.0305	0	0.9601	-31.7104**	0	0.000
SHSE B	-1.2495	4	0.6546	-14.2751**	3	0.000	-1.3179	1	0.6231	-29.0262**	0	0.000
SZSE A	-1.8281	21	0.3670	-6.1215**	20	0.000	-0.8483	3	0.8043	-17.2490**	2	0.000
SZSE B	-1.6137	8	0.4752	-8.4911**	7	0.000	-0.9862	3	0.7599	-17.4868**	2	0.000
DJI	-2.2986	0	0.1726	-32.1873**	0	0.000	-0.8966	7	0.7896	-13.5038**	6	0.000
HSI	-1.3693	0	0.5985	-31.2839**	0	0.000	-0.4338	1	0.9008	-30.6295**	0	0.000
H	-2.8616	13	0.0503	-8.0551**	12	0.000	-1.3224	20	0.6210	-7.2013**	19	0.000

Note: The ADF test is calculated from the levels and the returns of the variables SHSE A, SHSE B, SZSE A, SZSE B, DJI, HSI and H for the two subsamples. The lag length is selected by the Akaike information criterion. ** indicates significance at the 1% level.

Dickey Fuller (ADF) test for both levels and first differences. The results are displayed in table 1.[14] The optimal lag length in the test specification is determined by the Akaike information criterion. All data series are non-stationary in levels but stationary in first differences in both subsamples, at least at the 5% significance level.

Table 2 contains the summary statistics for the return series of both subsamples. These statistics include the mean, the maximum, the minimum, the standard deviation and the range. The mean is nearly zero in all cases. The ranges and the standard deviations seem to decrease in the second subsample compared to the first. In contrast to the findings of Brooks and Ragunathan (2003), the standard deviation of the A share index in both exchanges is lower than for the B share index as reported by Chen et al. (2006).[15] This may indicate a higher risk of trading B shares.

In table 3 we depict the bivariate correlations between the five Chinese variables (SHSE A, SHSE B, SZSE A, SZSE B and H) with the DJI as well as the HSI index of the pre- and post-liberalization sample.

[14]The ADF test is conducted allowing for an intercept. Allowing for a trend when the returns are tested does not change the results.

[15]Additionally, Brooks and Ragunathan (2003) find negative average returns for both B share indices. They also report a higher standard deviation of A shares in comparison to B shares which is in contrast to our results. However, their sample period ranges from January 1994 to October 1998 including - contrary to our sample - the Asian financial crisis in 1997.

Table 2: Descriptive Statistics of the Index Return Series

	Mean	Max	Min	Std.Dev.	Range	Mean	Max	Min	Std.Dev.	Range
Pre-liberalization						Post-liberalization				
SHSE A	0.0000	0.0940	-0.0792	0.0145	0.1732	0.0004	0.0790	-0.0551	0.0123	0.1341
SHSE B	0.0012	0.0945	-0.1029	0.0258	0.1974	0.0000	0.0921	-0.0877	0.0159	0.1798
SZSE A	0.0000	0.0924	-0.0833	0.0153	0.1747	0.0002	0.0765	-0.0606	0.0131	0.1371
SZSE B	0.0010	0.0940	-0.0997	0.0266	0.1937	0.0007	0.0780	-0.0660	0.0155	0.1440
DJI	0.0000	0.0615	-0.0740	0.0131	0.1355	0.0003	0.0353	-0.0367	0.0077	0.0720
HSI	0.0000	0.0543	-0.2152	0.0165	0.1472	0.0006	0.0360	-0.0418	0.0092	0.0778
H	0.0000	0.1011	-0.1219	0.0230	0.2230	0.0014	0.0665	-0.0803	0.0156	0.1468

Note: The different descriptive statistics for the index return series SHSE A, SHSE B, SZSE A, SZSE B, DJI, HSI and H are displayed.

Regarding regional and global stock market integration, these correlations suggest a more pronounced regional integration of China's stock markets. The correlations between China's indices as well as H shares and the HSI are much higher than the correlations with the DJI in both subsamples.[16] The hint of global integration is rather weak as the correlation coefficients are small. This holds for both in the pre-liberalization phase as well as after stock market liberalization efforts.

In the following sections we further assess the integration level of Chinese stock markets to regional and global markets by applying the Cheung and Ng (1996) procedure.[17]

[16] H shares represent an interesting alternative for foreign investors to participate in the Chinese stock markets because of lower trading barriers and trading costs while B shares, which were created for foreign investors, receive only little attention.

[17] An advantage of the Cheung and Ng (1996) approach compared to prior methods is the consideration of first- and second-moment dynamics. Additionally, the Cheung and Ng procedure is very useful as it is asymptotically robust to violations of the distributional assumptions.

Table 3: Correlation between Chinese stock market indices and those from Hong Kong and the United States

	Pre-liberalization	Post-liberalization		Pre-liberalization	Post-liberalization
SHSE A and DJI	-0.0284	0.0200	SHSE A and HSI	0.0971	0.1068
	(0.3594)	(0.5194)		(0.0017)	(0.0005)
SHSE B and DJI	-0.0049	-0.0062	SHSE B and HSI	0.1227	0.1020
	(0.8755)	(0.8410)		(0.0001)	(0.0010)
SZSE A and DJI	-0.0323	0.0233	SZSE A and HSI	0.0991	0.1038
	(0.2962)	(0.4512)		(0.0013)	(0.0008)
SZSE B and DJI	0.0087	0.0267	SZSE B and HSI	0.1462	0.1594
	(0.7797)	(0.3886)		(0.0000)	(0.0000
H and DJI	0.0649	0.0727	H and HSI	0.4766	0.7093)
	(0.0361)	(0.0188)		(0.0000)	(0.0000)

Note: The different bivariate correlations between the index return series for the two subsamples are displayed. The values in parentheses indicate the probability values.

4 Univariate Dynamics

In order to adjust the most parsimonious models, we apply ARMA(l,m)-GARCH(1,p)-M models (see equation 1 and 2) to the index return series R_t. The choice of l, m and p is carried out among l=0,...,5, m=0,...,5 and p=1,...,5 using residual diagnostics and the Akaike information criterion.[18]

$$ARMA(l,m) - GARCH(1,p) - M$$

$$R_t = \alpha_0 + \sum_{i=1}^{k} \alpha_i R_{t-i} + \sum_{i=1}^{l} \beta_i u_{t-i} + \gamma_1 h_t + u_t \tag{1}$$

$$h_t = \omega_0 + \sum_{i=1}^{p} \omega_i u_{t-i}^2 + \varphi_1 h_{t-1} \tag{2}$$

and

$$u_t \sim N(0, h_t)$$

An overview of the maximum-likelihood estimations and diagnostic statistics of the selected models is presented in table 4. Bollerslev and Wooldridge (1990) standard errors which are robust to non-normality in dynamic models are used. In addition, the Ljung-Box Q-statistics

[18]The Bernd-Hall-Hall-Hausman algorithm is used.

for the first 6 and 12 autocorrelations of the standardized residuals - defined as $u_t/\sqrt{h_t}$ - and their squares are not significant at the 5% level indicating that the selected models provide an admissible description of our index return series.[19]

Different temporal dynamics before and after the implementation of the QFII program are reported. In the mean equation, the constants and the ARMA terms show relatively small values and are mostly insignificant. In contrast, all return series display considerable persistence in the conditional variance as φ_1 ranges between 0.58 and 0.98. Almost all coefficients are significant at the 5% level except of the lagged error terms of the H shares in the variance equation. The value of the lagged conditional variance increases in the second sample in all cases except for SHSE B, SZSE B and H, indicating increasing persistence to volatility shocks in the post-liberalization sample.

[19] In order to generate good diagnostic statistics we have to keep insignificant coefficients in some cases. Additionally, in the case of HSI we have to skip the constant in the mean equation.

Table 4: ARMA(l,m)-GARCH(1,p)-M Models for the Index Return Series

I. ARMA(l,m)-GARCH(1,p)-M Models for the Shanghai Stock Exchange Return Series								
		SHSE A				**SHSE B**		
		Pre		**Post**		**Pre**		**Post**
Mean	α_0	-0.0015*	α_0	-0.0004	α_0	-0.0009	α_0	-0.0033
		(-0.0007)		(0.0012)		(0.0009)		(0.0017)
	β_1	0.0302	α_1	0.0026	β_1	0.0763*	α_1	0.0883*
		(0.0414)		(0.0319)		(0.0386)		(0.0380)
Variance	ω_0	0.0000	ω_0	0.0000	ω_0	0.0000**	ω_0	0.0000*
		(0.0000)		(0.0000)		(0.0000)		(0.0000)
	ω_1	0.2181**	ω_1	0.0533*	ω_1	0.1985**	ω_1	0.0721*
		(0.0762)		(0.0238)		(0.0458)		(0.0365)
	φ_1	0.6499**	φ_1	0.9056**	φ_1	0.7462**	φ_1	0.8143**
		(0.0789)		(0.0411)		(0.0488)		(0.1135)
Log-likelihood		3061.070		3129.307		2472.895		2882.378
Residual tests	Q(6)	4.344	Q(6)	6.700	Q(6)	7.425	Q(6)	3.096
		(0.501)		(0.244)		(0.191)		(0.685)
	Q(12)	11.305	Q(12)	13.104	Q(12)	12.114	Q(12)	7.942
		(0.418)		(0.287)		(0.355)		(0.718)
	$Q^2(6)$	1.174	$Q^2(6)$	10.307	$Q^2(6)$	4.496	$Q^2(6)$	1.646
		(0.947)		(0.067)		(0.480)		(0.896)
	$Q^2(12)$	2.326	$Q^2(12)$	14.753	$Q^2(12)$	8.222	$Q^2(12)$	3.074
		(0.997)		(0.194)		(0.693)		(0.990)
II. ARMA(l,m)-GARCH(1,p)-M Models for the Shenzhen Stock Exchange Return Series								
		SZSE A				**SZSE B**		
		Pre		**Post**		**Pre**		**Post**
Mean	α_0	-0.0016*	α_0	-0.0004	α_0	-0.0016	α_0	-0.0015
		(0.0007)		(0.0012)		(0.0010)		(0.0018)
	β_1	0.0364	β_1	0.0489	β_1	0.1032*	β_1	0.0920*
		(0.0412)		(0.0325)		(0.0416)		(0.0387)
Variance	ω_0	0.0000*	ω_0	0.0000	ω_0	0.0000**	ω_0	0.0000*
		(0.0000)		(0.0000)		(0.0000)		(0.0000)
	ω_1	0.2244**	ω_1	0.0482**	ω_1	0.2253**	ω_1	0.1227**
		(0.0719)		(0.0175)		(0.0431)		(0.0456)
	φ_1	0.6527**	φ_1	0.9279**	φ_1	0.6749**	φ_1	0.5821**
		(0.0749)		(0.0272)		(0.0585)		(0.1464)
Log-likelihood		3024.442		3076.295		2464.509		2895.016
Residual tests	Q(6)	4.963	Q(6)	6.316	Q(6)	8.038	Q(6)	5.752
		(0.420)		(0.277)		(0.154)		(0.331)
	Q(12)	15.429	Q(12)	13.453	Q(12)	15.750	Q(12)	8.086
		(0.164)		(0.265)		(0.151)		(0.706)
	$Q^2(6)$	1.266	$Q^2(6)$	7.692	$Q^2(6)$	1.684	$Q^2(6)$	3.470
		(0.938)		(0.174)		(0.891)		(0.628)
	$Q^2(12)$	1.750	$Q^2(12)$	11.411	$Q^2(12)$	3.735	$Q^2(12)$	7.998
		(0.999)		(0.409)		(0.977)		(0.714)
III. ARMA(l,m)-GARCH(1,p)-M Models for the Dow Jones Industrial and Hang Seng Return Series								
		DJI				**HSI**		
		Pre		**Post**		**Pre**		**Post**
Mean	α_0	-0.0017	α_0	0.0000				
		(0.0009)		(0.0005)				
	β_1	0.0027	β_1	-0.0509	α_1	0.0371	β_1	0.0217
		(0.0339)		(0.0302)		(0.0308)		(0.0170)
Variance	ω_0	0.0000*	ω_0	0.0000	ω_0	0.0000	ω_0	0.0000
		(0.0000)		(0.0000)		(0.0000)		(0.0000)
	ω_1	0.0703**	ω_1	0.0359**	ω_1	0.0410*	ω_1	-0.0522**
		(0.0175)		(0.0123)		(0.0164)		(0.0081)
							ω_2	0.0807**
								(0.0151)

	φ_1	0.8963**	φ_1	0.9487*	φ_1	0.9402**	φ_1	0.9542**
		(0.0208)		(0.0149)		(0.0244)		(0.0131)
Log-likelihood		3107.188		3685.118		2823.028		3448.618
Residual tests	Q(6)	3.203	Q(6)	1.964	Q(6)	3.263	Q(6)	1.386
		(0.669)		(0.854)		(0.766)		(0.926)
	Q(12)	9.792	Q(12)	12.182	Q(12)	9.132	Q(12)	4.295
		(0.549)		(0.350)		(0.610)		(0.960)
	$Q^2(6)$	4.365	$Q^2(6)$	6.598	$Q^2(6)$	1.8053	$Q^2(6)$	6.087
		(0.498)		(0.252)		(0.875)		(0.298)
	$Q^2(12)$	6.703	$Q^2(12)$	8.205	$Q^2(12)$	3.198	$Q^2(12)$	10.060
		(0.823)		(0.695)		(0.988)		(0.525)

IV. ARMA(l,m)-GARCH(1,p)-M Models for the H Return Series

		H		
		Pre		Post
Mean	α_0	0.0000	α_0	0.0014
		(0.0010)		(0.0008)
	β_1	0.1401**	β_1	0.1345*
		(0.0324)		(0.0329)
Variance	ω_0	0.0000	ω_0	0.0000*
		(0.0000)		(0.0000)
	ω_1	0.1837**	ω_1	0.0695**
		(0.0594)		(0.0160)
	ω_2	-0.1059		
		(0.0654)		
	ω_3	0.0063		
		(0.0467)		
	ω_4	-0.0613		
		(0.0467)		
	φ_1	0.9775**	φ_1	0.9129**
		(0.0075)		(0.0201)
Log-likelihood		2545.559		2977.794
Residual test	Q(6)	2.471	Q(6)	3.907
		(0.781)		(0.563)
	Q(12)	9.382	Q(12)	8.950
		(0.587)		(0.627)
	$Q^2(6)$	4.262	$Q^2(6)$	6.557
		(0.512)		(0.256)
	$Q^2(12)$	12.630	$Q^2(12)$	12.505
		(0.318)		(0.327)

Note: The Maximum-Likelihood estimations of the appropriate ARMA(l,m)-GARCH(1,p)-M models are reported. The Bollerslev and Wooldridge (1990) asymptotic standard errors are in parentheses. * and ** indicate significance at the 5% and 1% level. Q(6), Q(12), $Q^2(6)$ and $Q^2(12)$ are the Ljung-Box Q-statistics and their p-values in parentheses for the first 6 and 12 autocorrelations of the standardized residuals and their squares.

5 Regional and Global Spillovers between Stock Market Indices

To reveal how the different indices are linked before and after the implementation of the QFII program, we apply the Cheung and Ng (1996) procedure based on the ARMA(l,m)-GARCH(1,p)-M models in table 4 and the cross correlation coefficients based on the residuals from the models which are reported in table 5.[20] The standardized residuals and their squares are used to test for causality in the conditional mean and conditional variance equation. The null hypothesis represents the case of no causality. To test causality-in-mean, the cross

[20] As the choice of the lag length is likely to affect the empirical results, we follow the suggestion of Hu et al. (1997). They use five leads/lags as this seems reasonable for daily closing prices.

Table 5: Cross Correlations of the Standardized Residuals

Pre-liberalisation										
	SHSE A and DJI		SHSE B and DJI		SZSE A and DJI		SZSE B and DJI		H and DJI	
Lag s	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares
1	-0.0297	0.0007	-0.0081	-0.0085	-0.0328	0.0121	-0.0053	0.0108	0.0485	**0.0798***
2	0.0170	0.0231	0.0576	0.0142	0.0214	0.0250	**0.0729***	0.0089	**0.1694***	**0.0620***
3	-0.0117	-0.0164	0.0126	0.0001	-0.0021	-0.0175	0.0027	0.0205	-0.0584	0.0500
4	**-0.0670***	0.0204	-0.0496	-0.0040	-0.0580	0.0201	-0.0519	-0.0009	**0.0711***	-0.0102
5	0.0410	-0.0113	0.0482	-0.0152	0.0376	-0.0107	0.0218	-0.0099	0.0297	-0.0152
	SHSE A and HSI		SHSE B and HSI		SZSE A and HSI		SZSE B and HSI		H and HSI	
Lag s	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares
1	0.0608	0.0454	0.0259	0.0248	**0.0664***	0.0472	0.0124	0.0319	-0.0422	-0.0098
2	0.0061	-0.0123	-0.0293	0.0338	0.0096	-0.0145	-0.0230	0.0296	-0.0029	-0.0068
3	**0.0772***	0.0358	0.0499	0.0380	**0.0720***	0.0386	0.0494	0.0517	-0.0131	0.0191
4	0.0412	-0.0094	0.0537	0.0165	0.0433	-0.0107	0.0468	0.0208	0.0231	0.0138
5	0.0367	-0.0258	-0.0475	-0.0234	0.0469	-0.0284	-0.0382	-0.0206	-0.0112	0.0525
Post-liberalization										
	SHSE A and DJI		SHSE B and DJI		SZSE A and DJI		SZSE B and DJI		H and DJI	
Lag s	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares
1	0.0187	0.0244	-0.0135	-0.0329	0.0195	0.0215	0.0247	0.0076	**0.0922***	0.0154
2	0.0233	-0.0157	0.0151	-0.0409	0.0105	-0.0103	**0.0735***	-0.0171	**0.2809***	**0.1446***
3	0.0555	0.0059	0.0363	-0.0488	0.0327	0.0155	0.0309	-0.0013	-0.0062	-0.0006
4	0.0069	-0.0053	0.0132	0.0056	-0.0019	-0.0145	0.0242	-0.0231	0.0491	-0.0187
5	0.0232	0.0155	0.0211	0.0466	0.0086	0.0165	0.0049	0.0495	0.0403	-0.0113
	SHSE A and HSI		SHSE B and HSI		SZSE A and HSI		SZSE B and HSI		H and HSI	
Lag s	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares	Levels	Squares
1	**0.0641***	-0.0176	0.0517	-0.0119	0.0391	-0.0070	**0.0929***	0.0015	-0.0601	-0.0231
2	-0.0253	-0.0312	-0.0204	-0.0236	-0.0327	-0.0178	-0.0251	-0.0228	**-0.0634***	-0.0582
3	-0.0026	-0.0130	0.0453	-0.0174	0.0038	-0.0132	0.0313	0.0115	-0.0098	-0.0213
4	-0.0015	-0.0043	0.0128	-0.0013	0.0026	-0.0065	0.0053	0.0040	-0.0097	-0.0205
5	0.0249	-0.0460	-0.0256	-0.0180	0.0170	-0.0330	0.0235	-0.0261	0.0495	-0.0185

Note: The cross correlations of the standardized residuals and the squared standardized residuals computed from the models reported in table 4 are shown. *s* is the number of periods the second cited return series lags the first cited return series. * indicates significance at the 5% level.

correlations of the standardized residuals are used while causality-in-variance is tested using the squares of the standardized residuals.

The indicated number of lags s reports the number of trading days the second cited return series lags the first cited return series. Spillovers in mean and in variance are indicated by significant cross correlation coefficients in both, levels and squares.

As the Dow Jones Industrial index operates in a different time zone, the interpretation of significant cross correlation coefficients related to the DJI has to take this time difference into account. Thus, especially significant cross correlation coefficients at lag 0 do not represent situations with endogeneity problems and should be interpreted as evidence that the Dow Jones Industrial index affects the first cited return series. Therefore the indicated lag s in these cases is factually lag s-1.

The results in table 5 report evidence of causal interactions in both subsamples.

Causality-in-mean is reported from DJI to SHSE A, to SZSE B and to H shares in the pre-liberalization phase. In the post-liberalization phase the causality-in-mean from DJI to SHSE A disappears while the other two effects still persist although partly at different lags. Causality-in-variance is found from DJI to H shares in both subsamples. This causality pattern indicates that the liberalization of the A share segment does not lead to a higher global integration of Chinese stock markets as DJI's variance does not spill over to more share segments in the second subsample.

Interestingly, we find similar results when analyzing regional integration. While causality-in-mean is indicated in the pre-liberalization phase from HSI to SHSE A and to SZSE A and additionally from HSI to SHSE A, SZSE B, and H, in the post-liberalization phase, no causality-in-variance is displayed. This suggests that the liberalization of Chinese A share segment does not enhance Chinas' stock market integration with regional stock markets. However, at this stage of analysis, we have to interpret these causalities with caution as we do not check if the causality is actually caused by the foreign market. For this we control in the next step.

To further investigate the causality patterns of Chinese stock markets and to verify if the significance in the cross correlations is actually caused by the foreign stock markets, we use these information on the interactions in mean and variance between the time series in the next step to construct augmented ARMA(l,m)-GARCH(1,p)-M models. The effect of one equity return series on the other is incorporated by adding the significant lagged (squared) returns of the 'foreign markets' in the mean and variance equation of the original ARMA(l,m)-GARCH(1,p)-M models reported in table 4. With these new models, we indicate whether the reported spillover effects in mean and in variance are caused by the foreign return series. In addition, we avoid potential spurious evidence of causality-in-variance caused by unconsidered causality-in-mean and vice versa.

In equations 3 and 4 the foreign markets are captured by R^*_{t-i} and R^{*2}_{t-i}. Table 6 reports the augmented ARMA(l,m)-GARCH(1,p)-M models of the equity return series.[21]

[21] Not all intermediate models are shown. In some cases, adding significant variables lead to more significant cross correlations which are considered in further steps. Only the estimations of the final augmented models are shown in table 6.

$$R_t = \alpha_0 + \sum_{i=1}^{k} \alpha_i R_{t-i} + \sum_{i=1}^{l} \beta_i u_{t-i} + \gamma_1 h_t + u_t + \sum_{i=0}^{m} \delta_i R^*_{t-i} \tag{3}$$

$$h_t = \omega_0 + \sum_{i=1}^{p} \omega_i u^2_{t-i} + \varphi_1 h_{t-1} + \sum_{i=0}^{n} \lambda_i R^{*2}_{t-i} \tag{4}$$

In most cases the added lagged foreign return series in the mean equation are significant (at least at the 10% level). However, the added squared lagged foreign return series in the variance equation are not significant at the conventional levels and the Q-statistics are insignificant at least at the 5% level.

Table 6: Augmented ARMA(l,m)-GARCH(1,p)-M Models for the Index Return Series

	I.SHSE A and DJI		**II.SZSE B and DJI**			
		Pre		Pre		Post
Mean	α_0	-0.0014*	α_0	-0.0014	α_0	-0.0015
		(0.0007)		(0.0010)		(0.0018)
	β_1	0.0343	β_1	0.1014*	β_1	0.0887*
		(0.0414)		(0.0414)		(0.0388)
	δ_3	-0.0564*	δ_1	0.1259**	δ_1	0.1120*
		(0.0283)		(0.0441)		(0.0523)
Variance	ω_0	0.0000	ω_0	0.0000**	ω_0	0.0000*
		(0.0000)		(0.0000)		(0.0000)
	ω_1	0.2275**	ω_1	0.2238**	ω_1	0.1241**
		(0.0764)		(0.0437)		(0.0458)
	φ_1	0.6358**	φ_1	0.6781**	φ_1	0.5780**
		(0.0831)		(0.0592)		(0.1471)
Log-likelihood		3053.080		2465.364		2896.875
Residual tests	Q(6)	4.564	Q(6)	7.448	Q(6)	5.6271
		(0.472)		(0.189)		(0.344)
	Q(12)	12.417	Q(12)	14.915	Q(12)	7.970
		(0.333)		(0.185)		(0.716)
	$Q^2(6)$	1.157	$Q^2(6)$	1.701	$Q^2(6)$	3.560
		(0.949)		(0.889)		(0.614)
	$Q^2(12)$	2.251	$Q^2(12)$	3.479	$Q^2(12)$	8.3973
		(0.997)		(0.983)		(0.677)

	III. H and DJI			
		Pre		Post
Mean	α_0	0.0004	α_0	0.0012
		(0.0010)		(0.0007)
	β_1	0.1403**	β_1	0.1116**
		(0.0326)		(0.0324)
	δ_2	0.2570**	δ_0	0.1077*
		(0.0385)		(0.0497)
	δ_4	0.1019*	δ_2	0.4464**
		(0.0443)		(0.0554)
Variance	ω_0	0.0000*	ω_0	0.0000
		(0.0000)		(0.0000)
	ω_1	0.1914**	ω_1	0.0659**
		(0.0503)		(0.0159)
	ω_2	-0.1353*		
		(0.0626)		
	ω_3	0.0725		
		(0.0619)		
	ω_4	-0.1084*		
		(0.0451)		
	φ_1	0.9787**	φ_1	0.9177**
		(0.0077)		(0.0177)
	λ_1	0.1523*	λ_2	0.0173
		(0.0750)		(0.0164)
	λ_2	-0.1485*		
		(0.0747)		
Log-likelihood		2557.795		3015.189
Residual tests	Q(6)	4.379	Q(6)	3.902
		(0.496)		(0.564)
	Q(12)	13.263	Q(12)	7.785
		(0.277)		(0.732)
	$Q^2(6)$	3.459	$Q^2(6)$	5.779
		(0.630)		(0.328)
	$Q^2(12)$	14.810	$Q^2(12)$	11.808
		(0.191)		(0.378)

	IV. SHSE A and HSI				**V. SZSE A and HSI**			
	Pre		Post		Pre			
Mean	α_0	-0.0013**	α_0	-0.0005	α_0	-0.0014**		
		(0.0007)		(0.0012)		(0.0006)		
	β_1	0.0176	α_1	-0.0018	β_1	0.0233		
		(0.0415)		(0.0326)		(0.0414)		
	δ_1	0.0450	δ_1	0.0641	δ_1	0.0455		
		(0.0293)		(0.0382)		(0.0297)		
	δ_3	0.0407			δ_3	0.0356		
		(0.0247)				(0.0250)		
Variance	ω_0	0.0000*	ω_0	0.0000*	ω_0	0.0000*		
		(0.0000)		(0.0000)		(0.0000)		
	ω_1	0.2350**	ω_1	0.0532*	ω_1	0.2374**		
		(0.0775)		(0.0237)		(0.0711)		
	φ_1	0.6221**	φ_1	0.9035*	φ_1	0.6315**		
		(0.0842)		(0.0410)		(0.0779)		
Log-likelihood		3054.226		3130.569		3017.226		
Residual tests	Q(6)	3.922	Q(6)	6.666	Q(6)	4.296		
		(0.561)		(0.247)		(0.508)		
	Q(12)	10.320	Q(12)	12.859	Q(12)	14.472		
		(0.502)		(0.303)		(0.208)		
	$Q^2(6)$	1.363	$Q^2(6)$	10.824	$Q^2(6)$	1.464		
		(0.928)		(0.055)		(0.917)		
	$Q^2(12)$	2.549	$Q^2(12)$	15.372	$Q^2(12)$	1.968		
		(0.995)		(0.995)		(0.999)		
	VI. SZSE B and HSI				**VII. H and HSI**			
			Post				Post	
Mean			α_0	-0.0018			α_0	0.0014
				(0.0018)				(0.0008)
			β_1	0.0803*			β_1	0.1252*
				(0.0398)				(0.0336)
			δ_1	0.1694**			δ_2	-0.0868
				(0.0520)				(0.0466)
Variance			ω_0	0.0000*			ω_0	0.0000*
				(0.0000)				(0.0000
			ω_1	0.1311**			ω_1	0.0679**
				(0.0461)				(0.0159)
			φ_1	0.5552**			φ_1	0.9147**
				(0.1358)				(0.0201)
Log-likelihood				2900.577				2979.426
Residual tests			Q(6)	5.534			Q(6)	4.976
				(0.354)				(0.419)
			Q(12)	8.181			Q(12)	9.986
				(0.697)				(0.532)
			$Q^2(6)$	3.780			$Q^2(6)$	5.756
				(0.582)				(0.331)
			$Q^2(12)$	7.677			$Q^2(12)$	11.746
				(0.742)				(0.383)

Note: The Maximum-Likelihood estimations of the appropriate ARMA(l,m)-GARCH(1,p)-M models are reported. The Bollerslev and Wooldridge (1990) asymptotic standard errors are in parentheses. * and ** indicate significance at the 5% and 1% significance level. Q(6), Q(12), $Q^2(6)$ and $Q^2(12)$ are the Ljung-Box Q-statistics and their p-values in parentheses for the first 6 and 12 autocorrelations of standardized residuals and their squares, respectively. R^* and R^{*2} indicate the (squared) return of the "foreign" market.

Table 7: Cross Correlations from the Augmented Models

Pre-liberalization								
	SHSE A and DJI				SZSE B and DJI		H and DJI	
Lag s	Levels	Squares			Levels	Squares	Levels	Squares
1	-0.0307	0.0013			-0.0037	0.0116	0.0521	0.0465
2	0.0140	0.0236			0.0006	0.0020	0.0164	0.0213
3	-0.0108	-0.0173			0.0118	0.0169	-0.0368	0.0592
4	-0.0084	0.0210			-0.0476	-0.0009	0.0192	-0.0124
5	0.0387	-0.0099			0.0234	-0.0112	0.0369	-0.0391
	SHSE A and HSI		SZSE A and HSI					
Lag s	Levels	Squares	Levels	Squares				
1	0.0058	0.0458	0.0123	0.0479				
2	0.0071	-0.0102	0.0106	-0.0124				
3	0.0291	0.0359	0.0317	0.0389				
4	0.0366	-0.0110	0.0395	-0.0123				
5	0.0381	-0.0263	0.0483	-0.0291				
Post-liberalization								
					SZSE B and DJI		H and DJI	
Lag s					Levels	Squares	Levels	Squares
1					0.0252	0.0082	0.0404	0.0165
2					0.0188	-0.0228	0.0552	**0.0761***
3					0.0399	-0.0006	-0.0415	0.0015
4					0.0242	-0.0205	0.0494	-0.0005
5					0.0035	0.0499	0.0346	0.0015
	SHSE A and HSI				SZSE B and HSI		H and HSI	
Lag s	Levels	Squares			Levels	Squares	Levels	Squares
1	0.0167	-0.0164			-0.0053	-0.0015	-0.0535	-0.0256
2	-0.0275	-0.0307			-0.0211	-0.0227	-0.0116	-0.0575
3	-0.0018	-0.0119			0.0327	0.0128	-0.0149	-0.0183
4	-0.0017	-0.0021			0.0062	0.005	-0.0096	-0.0209
5	0.0258	-0.0469			0.0258	-0.0285	0.0502	-0.0165

Note: The cross correlations of the standardized residuals and squared-standardized residuals computed from the models reported in table 4 are shown. k indicates the number of periods the second cited return series lags the first cited return series. * indicates significance at the 5% level.

The cross correlations from the augmented models reported above are shown in table 7.[22] Table 5 and 7 when taken together give a more complex picture about the spillover effects of the different markets and the changes before and after stock market liberalization. The consideration of the lagged foreign return series in the mean and variance equation in the ARMA(l,k)-GARCH(1,p)-M models leads to cross correlations which verify causality-in-mean in all cases and causality-in-variance in the case of H and DJI in the first but not in the second subsample.[23] These results show that the liberalization of the A share segment does not lead to more spillover effects in the post-liberalization phase neither in mean nor in variance.

Of particular interest, the fact that adding the foreign return series to the variance equation does not lead to insignificant cross correlations in the squares indicates that other factors play

[22] We only show the cross correlations for the augmented ARMA(l,m)-GARCH(1,p)-M models.

[23] Although the cross correlation of H and DJI in the second subsample is still significant, the value decreases substantially.

a more important role than the foreign return series.[24]

6 Conclusion

The change in the information flow triggered by the implementation of the QFII program allowing foreign institutional investors to trade A shares on the mainland China stock exchanges in Shanghai and Shenzhen, is analyzed with regard to the impact on Chinese stock market integration to the stock markets in Hong Kong and the United States. A two-stage Lagrange multiplier approach is applied to the return series of the stock indices.

Using ARMA(l,m)-GARCH(1,p)-M models and computing cross correlations of the (squared) residuals, we find some evidence of a more pronounced global rather than regional integration as more causality-in-variance is detected from DJI to H shares. However, our results indicate that the partial opening of the A share market to foreign institutional investors has not strengthen the integration of Chinese stock markets to other regional and global markets as volatility spillovers do not increase in the post-liberalization phase and apparently occur more often in the pre-liberalization phase. In our analysis, we do not find evidence that the indicated spillovers in variance in the post-liberalization phase are caused by the stock market in the United States. Therefore, it seems that other factors play a more crucial role and that trading barriers still exist.

News on regional or global stock markets are not transmitted to and incorporated into the prices of mainland China stock indices. These results may be a further evidence that China is decoupled from international and regional stock markets (emphasized for instance by Fidrmuc and Korhonen (2010)).

Our research could be extended in several ways. First of all higher frequency data (as in Susmel and Engle (1994)) would help a lot to understand and trace the information transmission among stock markets. Furthermore, as proposed by Hong et al. (2009) and Li et al. (2008), a weighting function could be used in order to consider the hypothesis that financial markets are

[24] Applying this procedure to the whole sample leads to the same results. While causality-in-mean is found between mainland China stock indices and DJI as well as HSI, causality-in-variance is only found and verified from DJI to H shares. Thus, our results indicate that stock market integration does not increase due to stock market liberalization. Using different indices, namely the Shanghai Stock Exchange Composite index, the Shenzhen Stock Exchange Composite index and the S&P 500, verified causality-in-mean is indicated for mainland China indices in the pre- and post-liberalization phase as well as validated causality-in-mean and causality-in-variance between H shares and the S&P 500 index, but again only in the pre-liberalization phase.

influenced the most by recent events and that the influence of past events gradually decrease. Additionally, an asymmetrical consideration of positive and negative innovations on changes in volatility could be incorporated (as in Johansson and Ljungwall (2009).

Another extension of our research would be to focus on the spread of financial crises and an explicit reference to the recent financial crises (as for instance done in Zhou et al. (2012). Knowledge about volatility transmission across emerging and developed stock markets may help to understand this phenomenon.

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