Common Influences, Spillover and Integration in Chinese Stock Markets[1]

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Abstract

The Chinese stock market features an interesting history of partition into domestic (A), foreigners' (B) and overseas (H) segments. This puts forth questions of integration of these markets as well as information transmission between them. We address these issues in a structural DCC framework, an econometric technique capable of identifying common factor influences from (bi-directional) spillovers as constituents of contemporaneous correlations. We find initial dominance of transmission from A to B and to a lesser extent from H to B. However, since the opening of the B-market for Chinese citizens in 2001, common factors have largely replaced the direct spillovers.

Keywords: China, Stock Market, Integration, Causality, Correlation
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1 Introduction

In the recent two decades, the rapid development of the Chinese stock market has attracted a large number of domestic and international investors. One of the distinctive features of the Chinese stock market is the market segmentation, since three main types of stocks, i.e. A, B and H shares, are issued and traded in separate markets.

Both A and B markets are based in Mainland China. Denominated in Chinese currency renminbi, A shares are traded exclusively by Chinese citizens. B shares, which are denominated in US dollars on the Shanghai Stock Exchange (SHSE) and in HK dollars on the Shenzhen Stock Exchange (SZSE), were allowed to be traded only by foreign investors before February 2001. From February 2001, the B markets are also open to Chinese citizens who have deposit accounts in foreign currencies. H shares are traded on the Stock Exchange of Hong Kong (SEHK) and denominated in HK dollars.

The segmentation feature of the Chinese stock market has attracted great attention of researchers; for a concise review, see section 2.2. Understanding the bilateral relationships between the Chinese segmented stock markets, such as cross-market causalities, spillover effects, etc., are useful for investors who are to make portfolio decisions and for policy makers concerned with the development strategies of the Chinese stock market.

Compared to the A and H markets, which have experienced consistently fast development, the B market is much smaller in size and less active as an investment avenue. Since 2002, it has almost lost its function as raising foreign capital for domestic firms. Under this circumstance, whether the B market should develop independently, or merge into the A or H market, becomes one of the current concerns of the Chinese Securities Regulatory Commission.[4] To investigate the nature and scope of the integration and informational leadership between the A, B and H markets will shed critical lights on this issue.

For our empirical analysis, we adopt and modify the structural dynamic conditional correlation (SDCC) framework proposed by Weber (2008b). Daily market index series are deployed for the investigation. The sample is divided into two sub-periods, i.e. 1997-2001 and 2002-2008, in order to study the effects of the new policy implemented in February 2001, which allows domestic investors to access the B market. Results of preliminary tests show that there exists considerable contemporaneous cross-correlation of the returns, which might be caused by common factors that hit both the markets, or by contemporaneous spillover effects.

[4]"Is the mission of the B market over?", http://www.caijing.com.cn/topic/fforum/ (in Chinese)

A broad literature on theoretical and empirical finance concludes that the major price adjustment of liquid assets to arriving information is finished at least within one day. For example, this is formalised in the popular random walk hypothesis, which implies returns uncorrelated with lagged variables. Whether or not this hypothesis is *exactly* fulfilled, in daily data most commonalities in terms of cross-correlations will appear contemporaneous. Our main contribution addresses disentangling the sources of these correlations between the different Chinese stock markets, as there are common factors, spillovers originating in one and spillovers originating in the other market. In this, we can fully account for the concepts of informational leadership and market integration, including changes in these measures over time. In contrast, most of the relevant existing literature investigates interactions and causalities between the different markets by means of examining the cross-autocorrelation or Granger causality relying on reduced-form models.

The outcome of our empirical examination shows that before 2002, there was a strong contemporaneous spillover from the A market to the B market, while the unconditional correlation of the structural innovations is not significant. This indicates that commonality between the A and B market was primarily based on the informational leading role of the A market. In the second period, the large contemporaneous spillover from the A to the B is replaced by considerable fundamental correlation, besides a relative small spillover from the B to the A market. Evidently, common factors now dominate the comovement of the A and B market. Combined with the cointegrating relation found in the second period between the A and the B market, we conclude that the A and the B market have increasingly integrated.

For the B-H and A-H pairings, we find similar patterns: The first sub-period is dominated by causal spillovers (from H to B, respectively from A to H), which give way to correlated structural innovations after 2001. However, the interaction between B and H, and even more so between A and H, is far less developed than in the A-B case.

The remainder of the paper is organized as follows: Section 2 briefly introduces the history of the Chinese stock market and offers a review of the literature. Section 3 elaborates on the methodology of the SDCC model. Our empirical results are reported in Section 4. Section 5 summarizes our findings and presents the conclusion.

2 Background Review

2.1 A Brief Introduction to the Chinese Stock Market

Along with the rapid growth of the Chinese economy, the stock market in China has also expanded tremendously in the last two decades. Since the re-opening of the Shanghai Stock Exchange in December 1990 and establishment of a new one, the Shenzhen Stock Exchange in July 1991, the Chinese stock market has attracted a large number of domestic as well as foreign investors. By the end of 2006, there were 1434 companies listed on the Chinese stock exchanges. The market capitalisations of all stocks and of the negotiable stocks were about 43 and 12 percent of the GDP, respectively.[5]

Despite its rapid development, market segmentation has been a distinctive feature of China's stock market. On the SHSE and SZSE, two types of stocks, i.e. A shares and B shares, are traded. Denominated in Chinese currency (RMB), A shares are available exclusively to domestic investors. Starting in 1991, Chinese firms have been allowed to issue B shares to foreign investors. These B shares are denominated in US dollars on the SHSE and in HK dollars on the SZSE. Prior to February 2001, their trading was restricted exclusively to overseas investors, including overseas Chinese residing in Hong Kong, Macao and Taiwan.

In addition to A shares and B shares, since 1993, the Chinese government has encouraged Mainland Chinese companies to go to list on the Stock Exchanges of Hong Kong, London, New York and Singapore. Due to close economic and financial ties between Mainland China and Hong Kong, the SEHK has become the most important place for Chinese firms listing overseas. The shares of Chinese firms listed on SEHK are known as H shares, the corresponding price index of which is the Hang Seng China Enterprises Index.

By the end of 2006, there were 1325 Chinese A share and 108 B share firms listed on the SHSE and SZSE. Among them, 86 companies had issued both A shares and B shares. Meanwhile, of 143 H share firms listed on the Hong Kong exchange, 32 have also issued A shares. Under Chinese regulation, A and B shares, or A and H shares, issued by the same company, are legally identical and so their holders can enjoy the same voting and ownership rights. However, due to the facts that RMB is not a convertible currency and the H market is restricted such that only international investors can have access to, the A, B and H markets are in fact segmented.

[5]China Securities and Futures Statistical Yearbook, 2007.

The A and B markets were completely segmented prior to February 2001. The segmentation was largely the result of two considerations of the Chinese government. On the one hand, it wanted to attract foreign capital and to improve the corporate governance structure by means of permitting international investors to invest in the Chinese stock market. On the other hand, the government would not allow free outflow of capital from the country and foreign control of domestic firms.

In its early years, the B market expanded rapidly. The number of listed firms increased from only 9 in 1992 to 108 in 1999. International institutional investors showed great interest in the new investment opportunity and dominated the market. In the following years however, the B market fell into continuous stagnation. Since 1999 there have been only a few new listings on the B market.

Compared to the A market which has experienced consistently fast development, the B market is much smaller in size and less active as an investment avenue. By the end of 2006, the number of B share companies accounts for only 7.6 percent of all listed companies on the SHSE and SZSE. Its market capitalization is only about 1.4 percent of the total and about the same holds for the turnover in relation to the total market turnover.[6] In addition, the B share prices are at a great discount relative to A shares.

The adverse effects caused by lack of transparency and liquidity have hindered the development of the B market. Another contributing factor to its stagnation is the rapid development of the H market. As of the end of 2006, the market capitalization of H shares had reached about 38 percent of the total of A plus B shares. B shares and H shares have attracted the similar investors groups and capital tends to move between the two markets. In general, the performance of H shares is better than that of B shares, because only large and successful Chinese firms can be listed there. In addition, the requirements of corporate governance of these H share firms and shareholder protection for the buyers are more stringent than those for domestically listed companies (Wang and Iorio 2007). Meanwhile, the SEHK presents an efficient and well-regulated trading system. Its importance to international investors has led them to choose trading in China-related stocks in Hong Kong rather than invest in B shares within China (Kim and Shin 2000). Many institutional investors therefore left the B market and opted for H shares in Hong Kong. As a result, the proportion of institutional investors fell to 1.2 percent in 2001.

In February 2001, the Chinese Securities Regulatory Commission announced a new policy that allowed Chinese residents with a foreign currency deposit account to trade in B shares.

[6] China Capital Markets Development Report, 2008.

Attracted by the sizable discount of B share prices relative to A shares, Chinese investors opened a large number of trading accounts shortly after the announcement, resulting in a hike of B share prices that lasted for several months. Consequently, the discount rate was dramatically reduced. Since Chinese investors now can trade in B shares, the two markets are becoming closer.

Before the B market was opened to domestic investors, the investors' structure in the A and B markets was different. While investors in the A market were mostly individuals with little investment experience and limited resources for obtaining and analysing market information, those in the B market were dominated by international institutional investors who were more capable of processing information and quickly executing transactions accordingly (Kim and Shin 2000). After the opening of the B market to domestic investors, its investor structure has become increasingly like that of A shares. As of 2006, about 83 percent of investors in this market were individual investors from Mainland China. The proportion of foreign institutional investors in the total has declined to about 1.1 percent. But because the RMB is still not fully convertible, Chinese investors cannot buy and sell foreign currencies freely and the two markets are therefore still partially segmented.

2.2 Literature Review

The segmentation of Chinese stock markets has attracted great attention of researchers. Much empirical work concentrates on analysing the segmentation and linkages between Chinese stock markets, as well as integration of Chinese with international stock markets (Wang and Iorio, 2007; Girardin and Liu, 2007). Meanwhile, some studies investigate the issues concerning the discounts of B shares relative to A shares based on asset pricing models. Chan et al. (2008) and Chakravarty et al. (1998) show that information asymmetry explains a significant portion of the cross-sectional variation of the B share discounts. Ma (1996) finds evidence that the price differences between A shares and B shares are correlated with investors attitudes toward risk and correlation between B shares and foreign shares.

In addition, a large number of researchers focus on exploring causality or the lead-lag relations, as well as information transmission between the segmented Chinese stock markets.

Taking cross-autocorrelations as measures of the adjustment speed of stock prices to a common factor, several studies explore the lead-lag relation among different markets

(Chui and Kwok 1998; Kim and Shin 2000; Chan et al. 2007; Qiao et al. 2007). Various Granger-causality-type tests are conducted to examine the causalities between different markets (Kim and Shin 2000; Qiao et al. 2008). VAR and VECM models are applied to investigate lead-lag relations, long-run cointegration relationships among the different markets indices and short-run adjustment speed (Qiao et al. 2007; Chiang et al. 2008). Some studies apply GARCH models to investigate volatility spillover effects between the A, B and H markets (Qiao 2007).

While some studies use the aggregated market price indices, others apply the data of the firms dual-listed on the A and B, or A and H markets (Chan et al. 2007; Qiao 2007). Most of the studies use data of daily returns (Chui and Kwok 1998; Kim and Shin 2000; Qiao et al. 2008) or weekly returns (Chiang et al. 2008; Qiao et al. 2007). Because the information transmission usually takes place within hours, the contemporaneous relationship of different markets would not be detected if the daily data is used. Some authors (Chan et al. 2007) use high frequency intra-day transaction data to circumvent the simultaneity problem.

To characterize the impact of China's policy change on February 19, 2001, when the new policy allowed domestic investors to buy and sell B shares, most of the studies in the field tend to split their sample into two sub-sample periods.

The results of the empirical studies concerning the lead-lag relations and the information transmission between Chinese segmented stock markets are inconclusive.

Chan et al. (2007) use high frequency intra-day transaction data of the firms dual-listed on the different markets and find that, before February 2001, the A market led the B market in price discovery. After February 2001, there exists a causality from the B to the A market. For both sub-periods, the A market dominates the price discovery process. Based on a fractionally integrated VECM and GARCH models, Qiao et al. (2007) use weekly data of the stock prices from 1995 to 2005 and find evidence that A, B and Hong Kong stock markets are fractionally cointegrated. The A market is most influential in terms of both mean and volatility spillover effects. There are bi-directional volatility spillovers between the B market and the Hong Kong market, and unidirectional spillover from the A market to the Hong Kong market. The exploration of the causalities between A, B and H shares by Kim and Shin (2000) is conducted by measuring cross autocorrelation and applying Granger causality tests. They find that B shares tend to lead H shares from 1996. Although A shares tend to lead B shares before 1996, such relations have either disappeared or been reversed since 1996. Chui and Kwok (1998) examine cross-autocorrelations between price changes in A and B shares using daily returns from 1993 to 1996, and find that the information flow runs from B to A shares.

3 Methodology

To begin with, let us establish the key features of the SDCC model introduced by Weber (2008b). As has been discussed in the Introduction, this model serves to identify bi-directional spillovers and correlated innovations as sources of overall return correlation. We approximate the data generating process of the n stock indices in the vector y_t by the structural-form vector error correction model (SVECM) with lag length p

$$A\Delta y_t = \alpha\beta' y_{t-1} + \mu_1 + \mu_2 d_t + \sum_{j=1}^{p} B_j \Delta y_{t-j} + \varepsilon_t \ . \tag{1}$$

A and B_j, $j = 1, \ldots, n$ are $n \times n$ coefficient matrices, where the main diagonal elements in A are normalised to unity. μ_1 and μ_2 are n-dimensional parameter vectors, d_t denotes day-of-the-week dummies and ε_t is a vector of heteroscedastic innovations with unrestricted covariance matrix. β spans the space of the r cointegrating vectors, and α contains the corresponding adjustment coefficients. In case no cointegration exists between the I(1) stock indices, $\alpha\beta'$ has rank $r = 0$, leaving a simple SVAR in first differences or returns.

(1) represents a fully simultaneous system that fails identification by conventional methods. Therefore, in a first step we estimate the reduced-form VECM

$$\Delta y_t = \alpha^r \beta' y_{t-1} + \mu_1^r + \mu_2^r d_t + \sum_{j=1}^{p} B_j^r \Delta y_{t-j} + u_t \ . \tag{2}$$

All new coefficients are obtained by premultiplying A^{-1} in (1), therefore being marked by the superscript r for "reduced" as in $\alpha^r = A^{-1}\alpha$. Accordingly, the new residuals are given by $u_t = A^{-1}\varepsilon_t$.

Sentana and Fiorentini (2001) note that latent factor models like (1) become uniquely identifiable in presence of time-varying second moments. Elaborating our model into this direction, denote the conditional variances of the elements in ε_t by

$$\mathrm{Var}(\varepsilon_{jt}|I_{t-1}) = h_{jt}^2 \qquad j = 1, \ldots, n \ , \tag{3}$$

where I_{t-1} stands for the whole set of available information at time $t-1$. The standardised white noise residuals are obtained as

$$\tilde{\varepsilon}_{jt} = \varepsilon_{jt}/h_{jt} \qquad j = 1, \ldots, n \ . \tag{4}$$

The volatility dynamics are modelled by a set of univariate GARCH(1,1) processes. We will show in the empirical part that this adequately picks up the data properties in the Chinese stock markets. For $j = 1, \ldots, n$ we write

$$h_{jt}^2 = (1 - g_j - d_j)c_j + g_j h_{jt-1}^2 + d_j \varepsilon_{jt-1}^2 \ , \tag{5}$$

where c_j denotes the unconditional variance and g_j and d_j are GARCH and ARCH coefficients. The single variances are stacked into the vector $H_t = \begin{pmatrix} h_{1t}^2 & \ldots & h_{nt}^2 \end{pmatrix}'$.

While the fundamental factors in classical structural dynamic systems are uncorrelated, Weber (2008a) allows for common driving forces of the variables by identifying and estimating a constant conditional correlation (CCC) specification for the structural disturbances. Weber (2008b) extends this concept by introducing structural *dynamic* conditional correlation (SDCC), which represents a clearly more flexible set-up. For the conditional correlation matrix R_t, define

$$R_t = diag\{Q_t\}^{-1/2} Q_t \, diag\{Q_t\}^{-1/2} \ . \tag{6}$$

Therein, Q_t follows the process

$$Q_t = (1 - \alpha - \beta)\overline{Q} + \alpha \tilde{\varepsilon}_{t-1} \tilde{\varepsilon}'_{t-1} + \beta Q_{t-1} \ , \tag{7}$$

which corresponds to a standard GARCH(1,1) with parameters α and β. $\overline{Q}$ denotes the unconditional covariance matrix of the standardised residuals $\tilde{\varepsilon}_t$.

With R_t at hand, the conditional covariance-matrix Ω_t of the structural disturbances ε_t is defined as

$$\Omega_t = diag\{H_t\}^{1/2} R_t \, diag\{H_t\}^{1/2} \ . \tag{8}$$

Accounting for the discussion in Engle (2002) and given positive GARCH-variances, Ω_t is assured to be positive definite. This property carries over to the conditional covariance-matrix of the reduced-form residuals $u_t = A^{-1}\varepsilon_t$

$$\Sigma_t = A^{-1} \Omega_t (A^{-1})' \tag{9}$$

due to its quadratic form.

Weber (2008b) discusses identifiability of his SDCC model. In essence, he shows that a simultaneous system like (1) complemented by the structural second-moment processes contains less parameters than a fully general multivariate GARCH model in conventional reduced form. In addition, a sufficient condition is given by linear independence of the conditional variances.

The log-likelihood for a sample of T observations (complemented by an adequate number of pre-sample observations) under the assumption of conditional normality is constructed as

$$L(\theta) = -\frac{1}{2}\sum_{t=1}^{T}(n \log 2\pi + \log|\Sigma_t| + u_t'\Sigma_t^{-1}u_t) \ , \tag{10}$$

where the vector θ stacks all free parameters from $A, \alpha, \beta, \overline{Q}, c_j, g_j, d_j,\ j = 1, \ldots, n$. The estimation proceeds by maximising (10), simultaneously determining the coefficients governing the variances, correlations and spillovers. As assuming conditional normality is often problematic for financial markets data, we rely on Quasi-Maximum-Likelihood (QML, see Bollerslev and Wooldridge 1992). Numerical likelihood optimisation is performed using the BHHH algorithm (Berndt et al. 1974).

To facilitate practical estimation, we follow a three-step procedure: First, we estimate reduced-form VAR/VEC models as in (2). Then, the obtained residuals $\hat{u}_t$ are plugged into (10) in order to maximise the "concentrated" likelihood of the SDCC model. At last, with values of the spillover coefficients from A determined in the second step, the mean equations can be re-estimated, now in structural form.

4 Empirical Results

4.1 Data

We employ daily close data of the A and B indices from the Shanghai Stock Exchange (Shenzhen as robustness check) as well as the Hang-Seng China Enterprises Index from the Hong-Kong Stock Exchange ("H index"). Weekends and holidays are not contained in the sample. Figure 1 shows the log index development and the returns from 1/2/1992, the day the Shanghai A market started, until 5/30/2008.

In 2001, the B index made an enormous jump when the corresponding market was opened to Chinese citizens. Thereafter, A and B market seem to move closely together, partly in contrast to the preceding period. Throughout, idiosyncratic developments are most significant in the H index. The first years until 1996 seem to have constituted a difficult starting period for all markets. Concerning the returns, sizeable outliers and volatility characterised the A segment, while the B market appears rather inactive by that time. Indeed, trade volumes and turnover rates increased considerably in 1996 (e.g. Kim and Shin 2000). Since compared to previous studies, our sample is considerably elongate, we

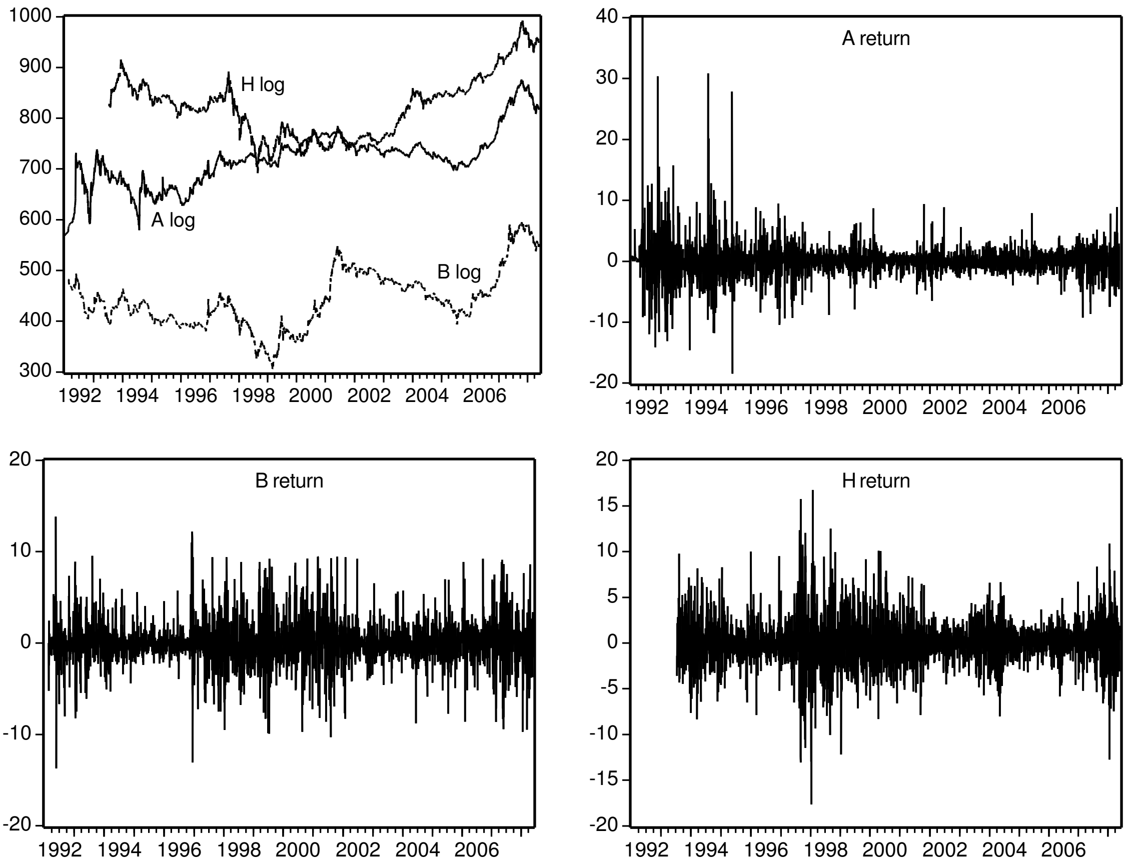

Figure 1: A, B and H indices and returns

cut the first years and begin in 1/3/1997.

Before we begin with the multivariate analysis, let us shortly establish the integration properties of the data. The ADF tests in Table 1 show that all indices (with constant and linear trend) are non-stationary, whereas the returns (with constant) are I(0).

Series	A index	B index	H index	A return	B return	H return
ADF statistic	-1.20	-1.52	-2.17	-54.88	-48.57	-47.11

Table 1: ADF tests

The contemporaneous cross-correlations of the returns can be found in Table 2. The A-B correlation is highest, followed by B-H. Additionally, the sample is split after 2001, when all repercussions of the A market opening from February seemed to have faded out. The correlations with the A returns are clearly higher in the second sub-sample, possibly a first sign of rising market integration. However, determining the structural sources for this phenomenon is one of the tasks for the following analysis.

	A-B	A-H	B-H
1997-2008	0.60	0.20	0.27
1997-2001	0.48	0.14	0.29
2002-2008	0.75	0.30	0.24

Table 2: Return correlations

4.2 Reduced-form Specifications

In the first step, we specify bivariate reduced-form VAR/VEC models as in (2) for the A-B, A-H and B-H indices in both periods, 1997-2001 (I) and 2002-2008 (II). We choose the lag length based on usual information criteria and check for no residual autocorrelation by means of LM tests. Table 3 displays the choices for p as well as LM p-values for different orders. These tests show that the relatively small but significant serial correlations from the raw return series are conveniently picked up by the model dynamics.

Series pair	A-B		A-H		B-H	
Period	I	II	I	II	I	II
Lag length p	4	6	2	4	3	4
LM(1) p-value	0.64	0.41	0.55	0.07	0.31	0.22
LM(2) p-value	0.80	0.14	0.37	0.18	0.31	0.13
LM(5) p-value	0.80	0.05	0.03	0.62	0.19	0.23
LM(10) p-value	0.85	0.29	0.22	0.49	0.06	0.39
Trace p-value	0.20	0.09	0.41	0.75	0.80	0.49

Table 3: Reduced-form specifications

Additionally, p-values for Johansen Trace tests with the null hypothesis of no cointegration ($r = 0$) can be taken from the last row of Table 3. Evidence for common trends does not emerge but at most in the second sub-sample between the A and B markets. In this case, we find furthermore that the hypothesis of equal weights in the long-run equilibrium, $\beta = (1, -1)'$, cannot be rejected by a likelihood ratio test with a p-value of 0.57. Consequently, the two Shanghai-based markets tend parallel in the long run since the B segment has been opened for Chinese citizens, whereas the Hong Kong market has an idiosyncratic development. Statistically, we proceed with a VECM for the second A-B period and with VARs in first differences in all other cases.

4.3 Spillovers, Fundamental Correlation and Structural Change

Now, in the second step, the residuals $\hat{u}_t$ obtained from the reduced-form models serve as input variables for estimating the SDCC model. The goal is to split up the important contemporaneous correlations (see Table 2) into its three constituents common influences, spillover in one and spillover in the other direction. We account for a possible break after 2001 by including shift dummies for the unconditional correlation parameter $\overline{q}$ (the off-diagonal element in $\overline{Q}$) and the spillover coefficients a_{12} and a_{21} (the off-diagonal elements in A). Particularly, the shift parameters indicate the change in these measures from the first to the second period. To enhance efficiency, the GARCH and DCC parameterisation, in which breaks are neither supposed nor of special interest, is held constant throughout the sample.

After the values for the spillover coefficients as entries in the A-matrix in (1) have been determined, this system is re-estimated to arrive at a full structural dynamic model in the last step. In both the SDCC and SVAR/SVECM estimation, parameters that failed to reach significance at the 10% level have been sequentially eliminated. The following results for the different models were obtained (deterministics and residuals not displayed):

A-B 1997-2001

$$\begin{aligned}
\Delta A_t &= \underset{(0.035)}{0.121}\Delta B_t - \underset{(0.015)}{0.033}\Delta B_{t-1} + \underset{(0.026)}{0.068}\Delta A_{t-4} \\
\Delta B_t &= \underset{(0.107)}{0.582}\Delta A_t - \underset{(0.047)}{0.095}\Delta A_{t-1} + \underset{(0.028)}{0.155}\Delta B_{t-1} - \underset{(0.025)}{0.043}\Delta B_{t-2} + \underset{(0.025)}{0.073}\Delta B_{t-3}
\end{aligned} \tag{11}$$

The first period between the A and B markets is dominated by a strong contemporaneous spillover from A to B, while the one in the reverse direction is much smaller. Lagged effects are rather weak. The unconditional structural correlation $\overline{q}$ is not significantly different from zero. This is, the commonalities between citizens' and foreigners' markets were mainly based on the informational leading role of the A market. In contrast, advantages of large foreign investors in information processing and financial management seemed to have played but a subordinate role.

A-B 2002-2008

$$\begin{aligned}
\Delta A_t &= \underset{(0.002)}{0.004}(A_{t-1} - B_{t-1}) + \underset{(0.035)}{0.121}\Delta B_t - \underset{(0.013)}{0.031}\Delta B_{t-4} - \underset{(0.020)}{0.052}\Delta B_{t-5} + \underset{(0.027)}{0.075}\Delta B_{t-6} \\
&\quad + \underset{(0.022)}{0.043}\Delta A_{t-3} + \underset{(0.025)}{0.047}\Delta A_{t-5} - \underset{(0.033)}{0.107}\Delta A_{t-6} \\
\Delta B_t &= \underset{(0.003)}{0.010}(A_{t-1} - B_{t-1}) - \underset{(0.034)}{0.249}\Delta A_{t-1} + \underset{(0.034)}{0.086}\Delta A_{t-2} + \underset{(0.030)}{0.053}\Delta A_{t-3} - \underset{(0.045)}{0.143}\Delta A_{t-6} \\
&\quad + \underset{(0.027)}{0.267}\Delta B_{t-1} - \underset{(0.027)}{0.076}\Delta B_{t-2} + \underset{(0.036)}{0.124}\Delta B_{t-6}
\end{aligned} \tag{12}$$

In contrast, in the second period the large contemporaneous spillover has completely disappeared. Logically, the considerable return correlation now relies on significant common influences as shown by $\overline{q} = 0.747$. Evidently, the B-market liberalisation led to strong integration of the A and B segments in the sense that new information hits both markets simultaneously and has not to be transmitted through observed movements in the A index. Interestingly, the instantaneous spillover from B to A, though relatively small, has not significantly changed; since foreigners are still restricted to the B market, its limited signalling function continues. In case equilibrium deviations appear, it is the B market which slowly closes the gap over time through its adjustment to the cointegrating relation.[7] Consequently, in a sense related to Hasbrouck (1995), discovery of the single efficient price of the two markets takes place in the A segment.

B-H 1997-2001

$$\begin{aligned} \Delta B_t &= \underset{(0.044)}{0.246}\Delta H_t - \underset{(0.024)}{0.061}\Delta H_{t-3} + \underset{(0.027)}{0.111}\Delta B_{t-1} - \underset{(0.027)}{0.054}\Delta B_{t-2} + \underset{(0.028)}{0.058}\Delta B_{t-3} \\ \Delta H_t &= \underset{(0.033)}{0.064}\Delta B_{t-2} + \underset{(0.028)}{0.170}\Delta H_{t-1} - \underset{(0.029)}{0.062}\Delta H_{t-2} \end{aligned} \qquad (13)$$

Bearing in mind the correlation results from Table 2, it is not surprising that the mutual influences between the B and H indices are relatively weak. Between 1997 and 2001, the contemporaneous H return exerts the main impact on the B market. $\overline{q}$ is not significantly different from zero, so that the limited commonalities are due to the signalling function of the SEHK. Obviously, Hong Kong was more important as an overseas outlet than the B segment, which had initially been supposed to take this role.

B-H 2002-2008

$$\begin{aligned} \Delta B_t &= \underset{(0.028)}{0.046}\Delta H_{t-1} + \underset{(0.026)}{0.084}\Delta H_{t-3} + \underset{(0.026)}{0.056}\Delta H_{t-4} + \underset{(0.025)}{0.094}\Delta B_{t-1} \\ \Delta H_t &= \underset{(0.025)}{0.090}\Delta H_{t-1} - \underset{(0.024)}{0.052}\Delta H_{t-2} \end{aligned} \qquad (14)$$

In the second period, again the contemporaneous influence on the B returns has vanished. Several lagged effects are left, however. The fundamental correlation now amounts to $\overline{q} = 0.264$. Even if this link stays rather weak, as in the A-B case we find again that transmission to the B segment has been replaced by common influences. The above explanation for this phenomenon is likely to carry over to the B-H relations: As early as

[7] The A market shows positive adjustment to such deviations, thereby nominally widening the gap. However, the value of 0.004 is economically small and does not impair system stability in presence of the much larger right-directed B market reaction.

well informed domestic investors have been allowed to participate in the B segment, the reason for its (limited) informational orientation towards Hong Kong has vanished.

A-H 1997-2001

$$\begin{aligned} \Delta A_t &= \underset{(0.028)}{-0.050}\Delta A_{t-2} \\ \Delta H_t &= \underset{(0.051)}{0.208}\Delta A_t + \underset{(0.027)}{0.158}\Delta H_{t-1} \end{aligned} \tag{15}$$

Between the A and H markets, we find a moderate contemporaneous spillover from A to H in the first period. The fundamental correlation of the innovations is zero. Literally speaking, information advantages in the domestic market seem to have outweighed the international rank of the SEHK.

A-H 2002-2008

$$\begin{aligned} \Delta A_t &= \underset{(0.022)}{0.075}\Delta H_{t-1} + \underset{(0.021)}{0.054}\Delta H_{t-3} + \underset{(0.021)}{0.054}\Delta H_{t-4} \\ \Delta H_t &= \underset{(0.025)}{0.090}\Delta H_{t-1} - \underset{(0.024)}{0.048}\Delta H_{t-2} \end{aligned} \tag{16}$$

The second period features a fundamental correlation of $\overline{q} = 0.261$, whereas the contemporaneous spillover has disappeared. However, non-trivial lagged transmission from H to A can be established. All in all, the interactions between the major Chinese market and the Hong Kong based index are clearly least developed.

4.4 Conditional Variances and Correlations

The foregoing section has shown contemporaneous and dynamic interactions among the different markets as well as fundamental correlations of the structural shocks. We have not addressed yet the conditional variances and correlations, which are now at the centre of interest.

First, Table 4 summarises the estimates for the GARCH processes (5). The results are typical for financial data: All ARCH parameters are significant, lending credibility to our identification procedure, and the sum of ARCH and GARCH coefficients reveals considerable persistence. The fact that this measure is especially high for the H-market probably explains the indeterminacy of the unconditional volatility level c, which stands in contrast to the A and B results.[8]

[8] Besides, exactly the same can be observed in standard reduced-form univariate GARCH.

	A - B		A - H		B - H	
Constant c	2.832 (0.882)	5.720 (1.318)	2.879 (0.676)	10.53 (11.99)	5.874 (1.142)	11.19 (17.68)
ARCH d	0.103 (0.042)	0.174 (0.027)	0.106 (0.051)	0.099 (0.026)	0.182 (0.032)	0.095 (0.024)
GARCH g	0.875 (0.058)	0.774 (0.031)	0.864 (0.082)	0.897 (0.026)	0.758 (0.040)	0.901 (0.023)

Table 4: GARCH parameter estimates

Figure 2 shows the conditional variances of the three structural innovations.[9] All series share pronounced increases in 2007 and 2008, which have been preceded by a relatively calm period in the years before. The repercussions of the Asian financial crisis can be observed in the H-market, and to a lesser extent in the A and B segments. Somewhat differently, the 2001 economic and financial downturn left its mark particularly in the volatilities of the two mainland indices.

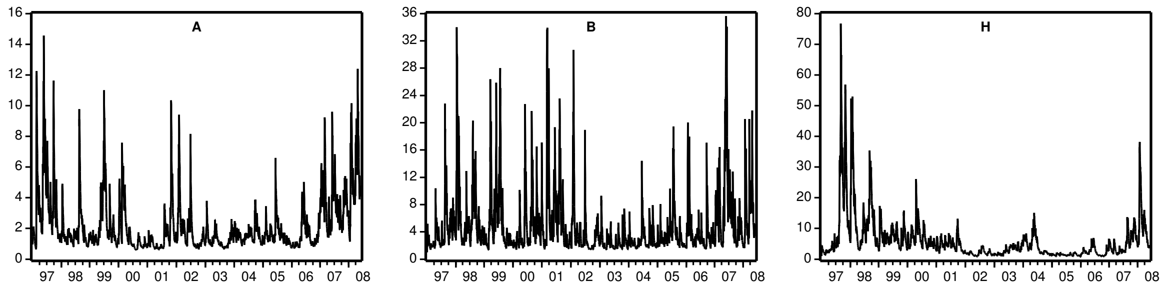

Figure 2: Structural conditional variances

It remains to demonstrate the merits of allowing for *dynamic* fundamental correlations. In Table 5 one can find the estimates for the DCC parameters from (7). For A-B and B-H, the coefficients are highly significant, implying time-varying structural correlations. In contrast, for A-H, past shocks did not significantly influence the conditional correlation, so that α and β were restricted to zero. In this case, including the structural break was obviously sufficient for modelling the change of correlation through time. The first row of zeros restates the lack of common influences on the structural innovations in the 1997-2001 period. For assessing this outcome, recall that here we are dealing with *fundamental* correlations of structural shocks; as the SVARs/SVECMs in the previous section have shown, causal contemporaneous spillovers additionally contribute a lot to the overall correlation, especially in the first period.

[9] In the three bivariate models, naturally each variance has been estimated twice. Since correlations are high and the optical impression is virtually identical, we opted arbitrarily for displaying the variances from the A-B model and the H variance from the A-H model.

	A - B	A - H	B - H
Constant $\overline{q}$ I	0 (–)	0 (–)	0 (–)
Constant $\overline{q}$ II	0.747 (0.039)	0.261 (0.025)	0.264 (0.054)
ARCH α	0.087 (0.025)	0 (–)	0.018 (0.006)
GARCH β	0.837 (0.053)	0 (–)	0.965 (0.012)

Table 5: DCC parameter estimates

The structural conditional correlations resulting from the processes addressed in Table 5 are displayed in Figure 3. Most importantly, all correlations rise over time, naturally including the distinct shift after 2001. Furthermore, for A-B and B-H the ups and downs characterising time-varying correlations become apparent. Weber (2008b) has argued that neglecting such variability is prone to understate the contribution of common influences to comovement of time series, lending undue weight to spillovers. Concretely, our SDCC specification plays an important role in identifying the deepening of Chinese stock market integration.

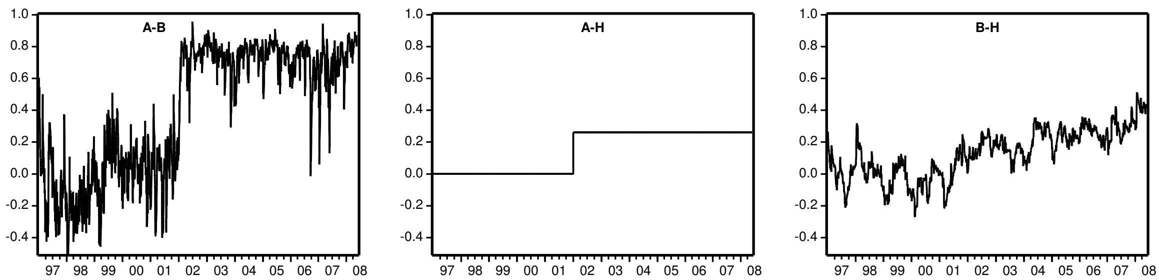

Figure 3: Structural conditional correlations

Finally, the models for the second moment are subjected to several specification tests: The vast majority of autocorrelations of the squared standardised disturbances $\tilde{\varepsilon}^2_{jt}$ and the cross products $\varepsilon_{1t}\varepsilon_{2t}$, standardised by the conditional covariances, do not exceed the approximate 95% confidence bands. Exceptions were the first order in the A-B model and the first and third orders of the H innovations. However, even those do not reach significance at the 1% level. The analysis was repeated using the reduced-form residuals u_t instead of ε_t. The constancy (apart from the break) of the conditional correlation in the A-H case was additionally checked by the procedure proposed in Engle and Sheppard (2001): In short, the cross products of the multivariately standardised (structural) residuals are tested to not follow an autoregression. Since the null is not rejected regardless of the AR order of the auxiliary model, our specification is confirmed.

4.5 Common Factors

Until here, we have learned about fundamental correlations and spillovers between the Chinese stock segments. An interesting question left to ask is what observable economic factors might explain our measurements. At the daily frequency, we have picked the Hang-Seng (Hong Kong), Straits Times (Singapore), Nikkei (Japan) and Dow Jones (USA) indices as well as the crude oil price (WTI Cushing) and the Chinese one-week interbank rate.[10]

The crucial point is how the significance of these variables for our findings of structural correlations and spillovers should be assessed. In order to integrate this additional analysis into the existing model framework, we opted for including the factors as exogenous variables in our structural equation systems. In case for example fundamental correlations conditional on the factors are significantly lower than in the baseline scenario, we can think of the market correlation being explained by common factor dependence. In detail, we first estimate the reduced form (2) including the additional regressors and then re-examine the SDCC with the new residuals.

Unsurprisingly, the Hang Seng return exerts by far the largest influence in the VARs/VECMs, which is however much smaller for A and B than for the H market. In all cases, the effect rises considerably in the second sub-period, what might indicate deepening stock market integration. Furthermore, the H market reacts to Straits Times returns, even if to a much lesser extent. The interest rate and oil price coefficients are estimated mostly negative, but none reaches statistical significance; the latter applies as well to the Dow Jones returns. Even though world market (respectively, US market) integration of Chinese stock exchanges is known to be limited, one should bear in mind that US and Chinese trading hours do not overlap, so that US innovations can hardly be expected to reveal the same immediate effect originating for example from the Hang Seng.

Concerning the structural parameters, relevant changes occur only in the A-H and B-H cases, but not in the A-B model. Obviously, the Hang Seng influence on the H market represents the only important factor. In the first sub-period, the instantaneous spillover effect from H to B falls from 0.246 to 0.180, and their fundamental correlation $\overline{q} = 0.264$ in the second sample half is reduced to 0.199. A-H is similar: In the first sub-period, the transmission to the H segment is lessened from 0.208 to 0.149, while the second

[10] Dow Jones and oil price have been lagged by one day due to the time shift. Observations on days not present in the Chinese stock series were deleted. Furthermore, missing values (compared to the Chinese stock series) were filled up by the preceding number.

sub-period structural correlation falls from 0.261 to 0.206. Whereas on the one hand, these impacts are not negligible, they are quite limited in size compared to the overall measures of market interaction obtained from the SDCC approach. Similar results of low explaining power of observables in equity models have been obtained for example by King et al. (1994). Evidently, once again this underlines the econometric merits of the current identification procedure for determining sources of stock market comovement in absence of comprehensive sets of observable explaining variables.

4.6 Robustness Checks

We have subjected our estimations to a battery of robustness checks. Since we encountered no decisive deviations, we just list the most important issues:

- SHSE has been picked as the largest Chinese stock exchange. However, using the leading indices of the not much smaller SZSE leaves the results unchanged.
- The choice of the lag length p did not prove crucial. This is not surprising, since we are mainly dealing with contemporaneous effects.
- It was not exactly clear at which date the structural break due to the B market opening should be set. While our date, the beginning of 2002, was chosen to take the evident market reactions into account, splitting the sample in February 2001 right after the liberalisation occured leads to no qualitatively different conclusions.
- In section 4.5, lags of the common factors could have been included. Doing so just wastes degrees of freedom for insignificant coefficients, except for several lagged Hang Seng returns.
- Apart from the most recent period, during our sample the Chinese exchange rate was almost fixed. Thus, we were able to replicate the results when all series were converted into a common currency.

5 Concluding Summary

The outcome of our empirical examination shows that before 2002, there was a strong contemporaneous spillover from the A market to the B market, and the unconditional structural correlation is not significant, which indicates that commonality between the A and B market is primarily based on the informational leading role of the A market. In the second period, the large contemporaneous spillover from the A to the B is replaced by the relative small spillover from the B to the A market, and the considerable return correlation relies on common factors.

Evidence of correlation, the contemporaneous spillovers and the common influences shows that the interaction between the B and the H market is relatively weak in both sub-periods. The transmission from the H to the B market in the first period is replaced by common influences in the second period.

Between the A and the H market, we find a moderate contemporaneous spillover from A to H in the first period, whereas the common influence is insignificant. In the second period the fundamental correlation is increased, but the contemporaneous spillover disappears. All in all, the interactions between the A and the H market are least developed.

We find cointegration between the prices of the A and B market since 2002. While the price of the A market is nearly weakly exogenous, the B price adjusts with respect to the cointegration deviations. This indicates that in the long run, the A market determines the common stochastic trend, respectively the efficient price in the sense of Hasbrouck (1995). In the meantime, the returns of the A and B markets have considerable contemporaneous correlation (0.747), representing common influences hitting the two markets. This indicates that in the short run, the A and B markets are closely integrated. The evidence that the A and B markets are becoming more and more integrated in both long run and short run since 2002 provides the prerequisite for the strategy that the B market merges into the A market. The close integration between the A and B markets might be explained by the fact the investors of the two market are becoming more similar after 2002. The H market is still segmented from the A and B markets until now.

TO BE FINISHED

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