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Common Influences, Spillover and Integration in Chinese Stock Markets

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Common Influences, Spillover and Integration in Chinese Stock Markets¹

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Abstract

The Chinese stock market features an interesting history of divided market segments: domestic (A), foreigners' (B) and overseas (H). This puts forth questions of market integration as well as cross-divisional information transmission. 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 and A to H. However, since the opening of the B-market for Chinese citizens in 2001, common factors have largely replaced direct spillovers.

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

JEL classification: C32, G10

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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 its distinctive features is the market segmentation, since three main types of stocks, namely 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 (RMB), 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 by legislation to be traded solely by foreign investors until February 2001. From then onwards, the B markets have been open to Chinese citizens with 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, concisely reviewed below in section 2.2. Understanding the bilateral relationships between the Chinese segmented stock markets, such as cross-market causalities, spillover effects, etc., is useful for investors' portfolio decisions and for policy makers concerned with developing strategies for the Chinese stock market.

Compared to the rather large A and H markets, which have experienced a consistently fast development, the B market is much smaller sized and less active as an investment avenue. Since 2002, it has almost lost its meaning in raising foreign capital for the domestic industry. This setting triggers the question whether the Chinese Securities Regulatory Commission shall support further independence of the B market or foster a merge into A or H market.⁴ For this, investigating the nature and scope of integration sheds light on the issue of informational leadership between the A, B and H markets.

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 this examination. The sample is divided into two sub-periods, 1997-2001 and 2002-2008. With this structure we can grasp the effects of the new policy, allowing domestic investors to access the B market, which was implemented in February 2001. Results of preliminary tests show that there exists considerable contemporaneous cross-correlation of returns, caused by common factors affecting both 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 major price adjustment of liquid assets happens at least within one day. This is formalised in the 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 appear to be contemporaneous. The main contribution of the underlying paper lies in disentangling the sources of these correlations between the different Chinese stock markets, as there are common factors, spillovers in one and such in the other direction. In this, we can fully account for the concepts of informational leadership and market integration, including changes in these measures over time. By doing so, we are reaching beyond relevant existing literature, which investigates interactions and causalities between different markets by means of cross-autocorrelations or Granger causality relying on reduced-form models.

The outcome of our empirical examination shows that before 2002, a strong contemporaneous spillover from A to B existed, whilst 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 A to B is replaced by a considerable fundamental correlation, let alone a relatively small spillover from B to A. 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 B market, we conclude that the two markets 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 paper is organized as follows: Section 2 briefly introduces the history of the Chinese stock market and offers a literature review. Section 3 elaborates the methodology of the SDCC model. Empirical results are reported in Section 4. Finally, section 5 summarizes and highlights our findings.

2 Background Review

2.1 A Brief Introduction to the Chinese Stock Market

Along with the rapid growth of the Chinese economy, also its stock market expanded tremendously during the last two decades. Since the re-opening of the Shanghai Stock Exchange in December 1990 and the additional establishment 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, 1434 companies were 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 (China Securities and Futures Statistical Yearbook, 2007).

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, A shares and B shares, are traded. Denominated in RMB, A shares are available exclusively to domestic investors. From 1991 onwards, 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 and B shares, since 1993, the Chinese government has encouraged Mainland Chinese companies to engage in foreign stock trading 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 the SEHK are known as H shares, its corresponding price index 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, allowing their holders equal voting and ownership rights. However, for the facts that RMB is non-convertible and the H market being restricted to international investors only, the A, B and H markets are in fact segmented.

Prior to February 2001, the A and B markets were completely divided. The segmentation

was largely the result of two considerations of the Chinese government. Firstly, authorities wanted to attract foreign capital and improve corporate governance by means of permitting international investors into the Chinese stock market. Secondly, the free outflow of capital from China as well as foreign control of domestic firms were intentionally suppressed.

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 opportunities 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 true for the turnover in relation to the total market turnover (China Capital Markets Development Report, 2008). In addition, the B share prices were at a great discount relative to A shares.

Adverse effects caused by the 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. By end of 2006, the market capitalization of H shares had reached about 38 percent of the total of A plus B shares. B and H shares have attracted similar investors groups shifting capital between the two markets. In general, the performance of H shares is better than that of B shares, because only large and viable Chinese firms are permitted listing. 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). As a result, the proportion of institutional investors decreased 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. Attracted by the sizeable discount of B share prices relative to A shares, Chinese investors restructured their asset portfolios towards B shortly after the announcement, resulting in

a hike of respective B share prices. Consequently, the discount rate was dramatically reduced. Ever since the two markets are aligning.

Before the B market was opened to Chinese citizens, the investors' structure in the A and B markets was different. While investors in the A market were mostly individuals with limited trading experience and resources for obtaining and analysing market information, those in the B market were dominated by international institutions capable of processing information and rapidly executing transactions accordingly (Kim and Shin 2000). After the opening of the B market to domestic traders, its mix of market players adopted to the pattern of the A market. As of 2006, about 83 percent of investors in this market were individuals 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 trade foreign currencies freely and the two markets therefore remain partially segmented.

2.2 Literature Review

The unique 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 issues concerning 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 issues or 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 lead-lag relations 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 analyse volatility spillover effects between the A, B and H markets (Qiao 2007).

While some studies focus on the aggregated market price indices, others apply data of firms dual-listed on the A and B, or A and H markets (Chan et al. 2007; Qiao 2007). Most deploy data of daily (Chui and Kwok 1998; Kim and Shin 2000; Qiao et al. 2008) or weekly returns (Chiang et al. 2008; Qiao et al. 2007). Some authors (Chan et al. 2007) apply high frequency intra-day transaction data to circumvent the simultaneity problem. To characterize the impact of China's policy change on February 19, 2001, allowing domestic investors to trade B shares, commonly data samples are split into two sets.

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

Chan et al. (2007) use high frequency intra-day transaction data of 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, estimated with weekly data of the stock prices from 1995 to 2005, Qiao et al. (2007) 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 autocorrelations and applying Granger causality tests. They find B shares in tendency to lead H shares from 1996 onwards. 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

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

A and B_j , $j = 1, \dots, n$ 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.

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

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

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-type 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

$$\text{Var}(\varepsilon_{jt}|I_{t-1}) = h_{jt}^2 \quad j = 1, \dots, n , \quad (3)$$

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

$$\tilde{\varepsilon}_{jt} = \varepsilon_{jt}/h_{jt} \quad j = 1, \dots, n . \quad (4)$$

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 $j = 1, \dots, n$ we write

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

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 $H_t = \begin{pmatrix} h_{1t}^2 & \dots & h_{nt}^2 \end{pmatrix}'$.

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

$$R_t = \text{diag}\{Q_t\}^{-1/2} Q_t \text{diag}\{Q_t\}^{-1/2} . \quad (6)$$

Therein, Q_t follows the process

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

which corresponds to a GARCH(1,1) with parameters α and β . \bar{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

$$\Omega_t = \text{diag}\{H_t\}^{1/2} R_t \text{diag}\{H_t\}^{1/2} . \quad (8)$$

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 $u_t = A^{-1}\varepsilon_t$

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

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

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

where the vector θ stacks all free parameters from $A, \alpha, \beta, \overline{Q}, c_j, g_j, d_j, j = 1, \dots, n$. 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 SEHK ("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 has significantly lengthened, we 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 $I(0)$.

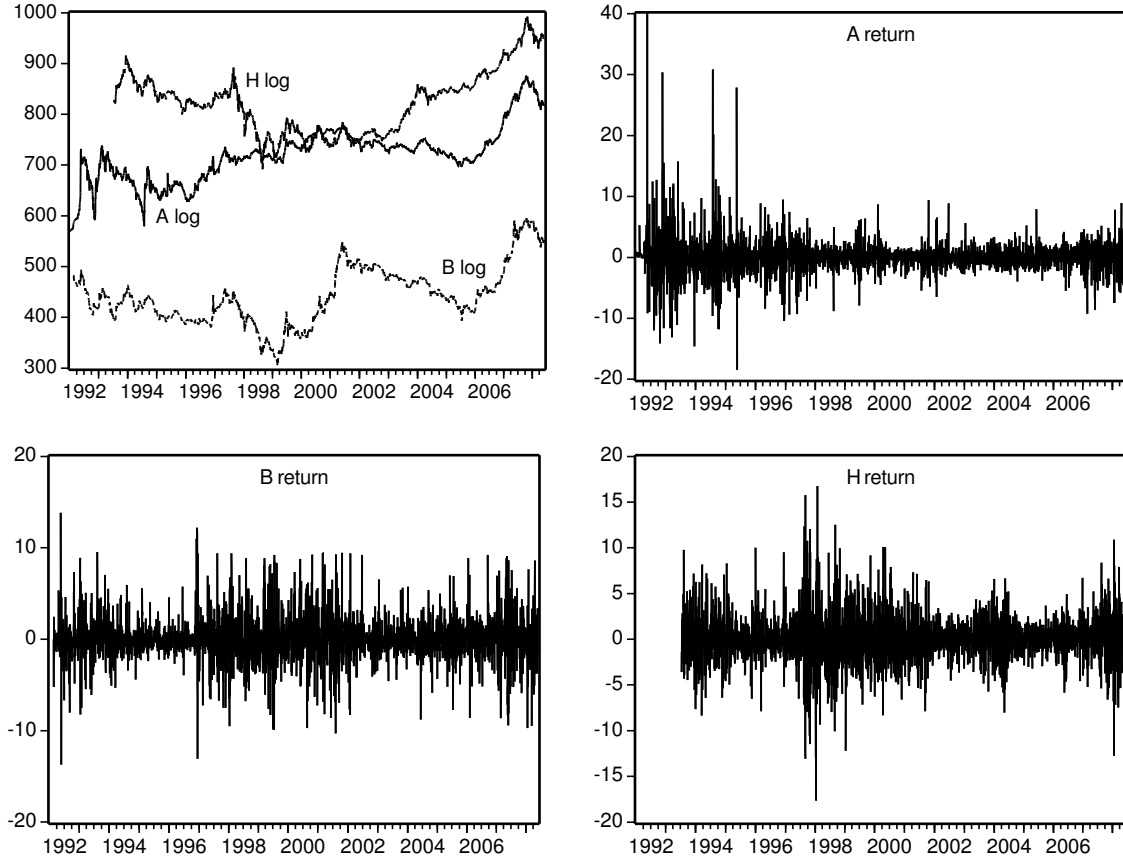


Figure 1: A, B and H indices and returns

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 the repercussions of the B market opening from February seem 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.

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

	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

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 Period	A-B		A-H		B-H	
	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 their three constituents common influences, spillovers in one and spillovers in the other direction. We account for a possible

break after 2001 by including shift dummies for the unconditional correlation parameter \bar{q} (the off-diagonal element in \bar{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

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

The interaction between the A and B markets in first period 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 \bar{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

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

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 $\bar{q} = 0.747$. 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.⁵ 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

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

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. \bar{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

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

In the second period, the contemporaneous influence on the B returns has vanished. Several lagged effects are left, however. The fundamental correlation now amounts to $\bar{q} = 0.264$. 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 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

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

⁵The 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.

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 statistically 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 $\bar{q} = 0.261$, 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 its unconditional volatility level c , which stands in contrast to the A and B results.⁶

	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

⁶Besides, exactly the same can be observed in standard reduced-form univariate GARCH.

Figure 2 shows the conditional variances of the three structural innovations.⁷ 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.

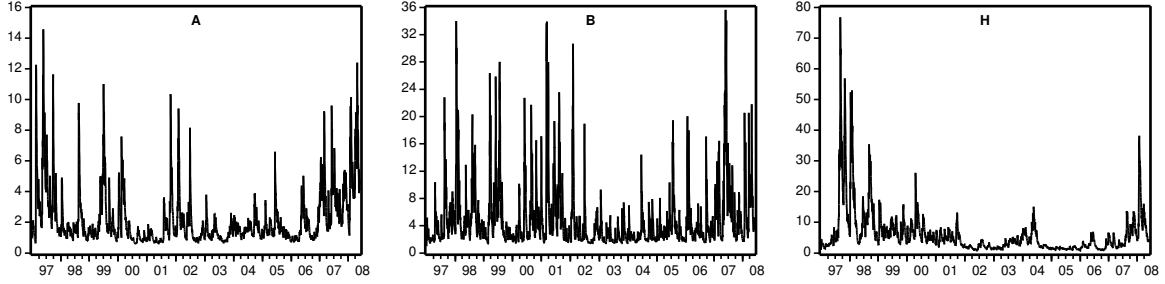


Figure 2: Structural conditional variances

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 return correlation, especially in the first period.

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

⁷In the three bivariate models, naturally each variance has been estimated twice. Since the visual 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 \bar{q} (I)	0 (-)	0 (-)	0 (-)
Constant \bar{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

integration.

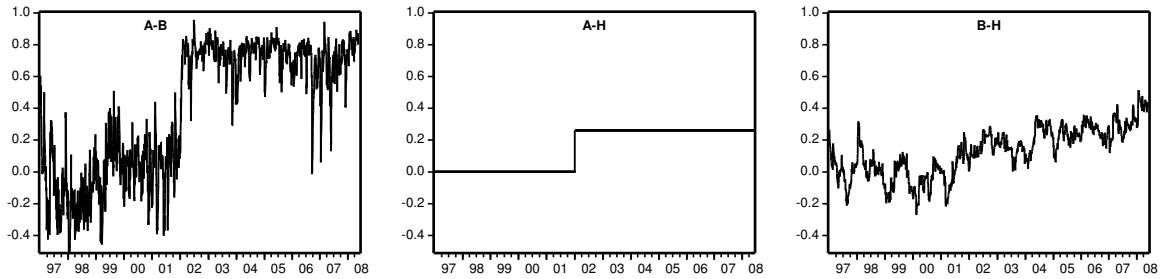


Figure 3: Structural conditional correlations

Finally, the models for the second moments are subjected to several specification tests: The vast majority of autocorrelations of the squared standardised disturbances $\tilde{\varepsilon}_{jt}^2$ 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.⁸

The crucial point is how 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 of them 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 $\bar{\varrho} = 0.264$ 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 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

⁸Dow 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.

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:

- The 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 occurred 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 few 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

In this paper, we have identified sources of contemporaneous correlation of stock markets, which can originate in both common influences hitting the markets and spillover effects between them. This way, we have empirically analysed integration and informational transmission between the Chinese segmented stock markets. The sample is divided into two sub-periods, before and after 2002, in order to characterize the impact of the B market opening to Chinese citizens. Methodologically, we adopted the new SDCC framework of Weber (2008b).

The outcome of our empirical examination shows that in general the integration of the A, B and H markets has significantly deepened in the second period. The A and B markets are more closely integrated compared to A and H or B and H. Before 2002, the main

contribution to the contemporaneous return correlations stemmed from causal spillovers. In contrast, since 2002 common factors dominate the correlation of the markets.

Concerning the interactions between the A and B markets, the spillover effects from A to B prior to 2002 indicate that commonality between A and B was primarily based on the leading role of A in terms of informational advantages. Since the B market was opened to Chinese citizens, common influences have become the main source of the rising correlation.

Compared to this process of integration, the H market is still more or less segmented even after 2002. In the first period, transmission runs from A to H and from H to B, whereas common influences are insignificant. These spillovers are replaced by fundamental correlations of the innovations in the second period, which are however limited in size. When exogenous factors are included as additional regressors in the system, we mainly find that Hang Seng and Straits Times returns affect H returns, especially after 2002. Obviously, the H market is to some extent linked to other important Asian stock markets, where the SEHK naturally proves most influential.

In a structural VECM, cointegration between the indices of the two markets A and B occurs since 2002. While the price of the A market is nearly weakly exogenous, the B price adjusts with respect to cointegration deviations; in the long run, the A market determines the common stochastic trend. In the sense of Hasbrouck (1995), this finding leads to the interpretation that the discovery of the efficient price takes place in the A market. This is likely to provide the prerequisite for a potential merge of the B into the A market, a strategy further supported by the evidence that both markets are moving towards close integration in both long and short run since 2002. The H market remains separate from the markets A and B for the time being.

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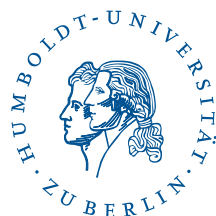
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