Visualizing the impact of policy changes: the case of dual-listed Chinese A and H shares

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Abstract
In this paper, we utilize daily price data of 70 China mainland companies cross listed in both Chinese A and H markets from January 2000 to August 2015 to examine the connection in the behavior of the same shares in different markets as well as among the 70 companies. To this end, we apply both network and price discovery methods. The price discovery measure provides index level results between two markets, while network measures show company level connections. We first apply the price discovery method and find the connection between price discovery contributions and regulation changes in mainland China. Based on these results, we can classify our data into eight periods, and then zoom into company level by applying network measures. We show clear evidence that mainland regulation changes affect price behavior of not only the mainland market itself but also dual-listed H shares, and in turn the Hong Kong market itself, to a certain extent. In terms of integration we find that dual-listed shares inter-connections are weak, with stocks more likely to be linked within the same market rather than with their dual-listed counter party.

Key Words: Price Discovery, Network, Dual-listed Stocks, Market Regulation
Impact of policy changes: the case of dual-listed Chinese A and H shares.

1 Introduction

The Chinese market as one of the largest emerging markets in the world has attracted interest from both researchers and investors around the world. Since 1994, when the first mainland listed stock became dual-listed in both the Shanghai and Hong Kong markets, research regarding dual-listed companies in Chinese markets began to appear. This topic is particularly interesting because of the difference between the two markets. The Chinese mainland market is a highly regulated market and government regulation is likely to have an effect on the performance of it, while the Hong Kong market is an open market with low regulation controls and as trading is based on Hong Kong dollars, which is pegged with the US dollar, there will be a link to international information.

Most recently in the middle of 2015, there was a large fall in the Chinese mainland stock market index, by 34.6% in two months. This event again alerted researchers that it is crucial to understand the impact of government regulation changes on both the mainland market and the Hong Kong market and the relation between dual-listed A and H shares. Many reports in the media have identified Chinese government regulation for the volatility (for example, such view was reported in ‘New York Times’, ‘CNN Hong Kong’, ‘Bloomberg’, ’Forbes’).

Literature regarding dual-listed shares in the Chinese market is abundant, and there is general support for the proposition that dual-listed A and H shares are becoming more integrated, see Peng, Miao & Chow (2008), Cai, McGuinness & Zhang (2011), Chen, Buckland & Williams (2011). Such an effect may arise from regulatory changes in the mainland market.

1 Chinese mainland stocks that are listed in the Shanghai or Shenzhen market are usually referred as A shares, and stocks of mainland companies that are listed in the Hong Kong market are usually referred as H shares.
In this paper, we build on previous literature on the topic of dual-listed A and H shares by incorporating regulation changes into the analysis. We apply two methods to investigate this issue; one is the price discovery measure following Hasbrouck (1995) and the other is the network measure following Buckle, Chen & Tong (2017).

We find clear evidence that regulation changes in the mainland market affect the behavior not only of the mainland market itself but also the dual-listed H shares. Moreover, with the number of dual-listed stocks increasing, these mainland market policies are likely to affect the whole Hong Kong market to a certain extent. Also, our results support past literature which finds that dual-listed shares are becoming more integrated over time. From our network measure, we identify a relation with government policy. Here, every sharp change in the linkage between A and H shares, either more or less integrated, occurs at the time a new policy is announced.

The paper adds to the literature in the following ways. First, we apply a new, network, method to examine the integration effect between dual-listed shares. Second, a visualized complex network of 140 stocks is presented in a dynamic fashion. Third, we test whether changes in mainland Chinese market policies also affect the Hong Kong market and not only the dual-listed H shares.

The rest of the paper is structured as follows. Section 2 examines literature regarding dual-listed companies. Section 3 describes the methodologies used in this research. Section 4 presents the empirical findings of this paper and section 5 concludes.

2 Literature Review

Literature regarding dual-listed shares is extensive, and such a topic is especially pertinent in Chinese market. Not only because mainland and Hong Kong markets have different regulation systems but also because the dual-listed companies are mainly state
owned companies or with a large proportion of shares held by the Chinese government.

We first look at literature regarding cross-listed shares in developed or open markets with less regulation restrictions. Eun & Sabherwal (2003) apply price discovery measure to examine the relationship between dual-listed shares. The authors collect price data for 62 Canadian firms that are dual-listed in Canada and the US between 2nd February and 31st July 1988 with an interval of 10 minutes. They use the Harris et al. (1995) permanent and transitory test to examine the price discovery contributions for shares listed in both countries from the same company, and report that the stocks listed in the home market (Canada) are contributing more to price discovery than those listed in the US, and that price adjustments are greater according to the changes happened in Canada. They also suggest that the stocks traded in the US have quicker price adjustments although these adjustments are following changes in Canada.

Lok & Kalev (2006) utilize daily price data of 63 dual-listed companies with 38 Australian companies and 25 New Zealand companies listed on the Australian Stock Exchange (ASX) and New Zealand Stock Exchange (NZX) between May 2000 and December 2002. The authors use a cointegration error correction model to examine the relationship between dual-listed shares as well as each listing’s contribution to price discovery. They report in terms of the contributions to the price discovery process, that home markets are always leading. Furthermore, they find the cross-listed shares are highly co-integrated and arbitrage opportunities generally do not exist.

De Jong, Rosenthal & Van Dijk (2009) examine the existence of arbitrage and the risk and return of arbitrage trading strategies in dual-listed shares. The authors apply a linear model to simulate an arbitrage trading strategy against 12 dual-listed European companies’ daily price data between 1980 and 2002. They report that there are about 10 percent of occasions when an abnormal return could be produced with a simple arbitrage trading strategy. However, they also suggest that the arbitrage opportunities would face great uncertainty, and such uncertainty could cause a large incidence of
negative returns which are likely to stymie the implementation of arbitrage trading strategies.

Agarwal, Liu & Rhee (2007) take a close look at the price discovery process and correlation cointegration between dual-listed shares by applying a weighted price contribution (WPC) method introduced by Barclay and Warner (1993) to an intraday data sample that covers 3 months between January 1996 and March 1996, the sample data consists of 17 Hong Kong – London dual-listed stocks. Their results suggest that most of the price discovery contribution is from the home market of these stocks, which is the Hong Kong market.

Past literature shows that the cross listed shares in developed markets are cointegrated to a very high level and the price discovery process is mainly from the home markets. Dual-listed companies whose home market is China present a different environment due to the political features.

Chakravarty, Sarkar & Wu (1998) look at the pricing of cross-listed Chinese A and B shares. They model Chinese A and B shares incorporating dummy variables for informational asymmetry and market segmentation. In order to capture B shares’ relation with foreign markets they include the Hang Seng index, Nikkei 225 index and S&P 500 index. Their data sample contains 39 dual-listed companies’ daily prices from January 1994 to December 1996. They report that B shares trade at an average discount of about 60 percent compared with A shares, and suggest that this discount is because foreign investors on B markets have less information on Chinese stocks.

Peng, Miao & Chow (2008) examine the price relation and convergence between dual-listed A and H shares. They build a non-linear regression for 38 dual-listed shares

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2 The Chinese market is a highly regulated market, foreign investors are not fully allowed to trade on it. The main Chinese market is closed to foreign investors which refers as A market, while the B market is only open to foreign investors.
between 22\textsuperscript{nd} July 2005 and 20\textsuperscript{th} June 2007. They report an increasing tendency for reduced price differences between dual-listed shares, but such a tendency is not clear in the period before deregulation in mainland China, but after the second phase of QFII\textsuperscript{3} they report a clear boost to price convergence.

Cai, McGuinness & Zhang (2011) examine the co-integration relationship between Chinese A- and H- shares. The authors use daily price data for 55 Chinese state-owned enterprises with dual-listed A- and H- shares and the sample period covers January 1999 to March 2009. The authors develop a non-linear Markov error correction model for this test and report that there is an overall tendency for dual-listed A and H shares to become co-integrated over time, and they find such a tendency is in line with Chinese government policies which are aimed at reforming China’s capital account regime and exchange rate system. Additionally, they report that the dual-listed H shares would help price transparency in the mainland market, and that the Chinese governance reformation helped spur price discovery in both A- and H- markets.

Tan, Chiang, Mason & Nelling (2008) examine the dynamic correlation structure between dual-listed shares in Chinese A and B markets. They use daily return data of 4 indices from two Chinese markets including both Shanghai and Shenzhen composite A and B indices; the data period covers from 1\textsuperscript{st} January 1996 to 30\textsuperscript{th} June 2003. They employ three methods to examine the correlation between A and B markets, which are basic correlation method, dynamic conditional correlation model (VGARCH-DCC) and GARCH based Cholesky decomposition method. The authors report that all of the three methods produce a consistent result that there is a positive trend of correlation between dual-listed A and B shares; additionally in relation to government policies, an announcement of reducing the barrier of trading further enhances co-movement between A and B markets.

\textsuperscript{3} QFII refers as qualified foreign institutional investors, it could be referred as an overseas fund management institution, insurance company, commercial bank, securities firm or asset management institution that invests in China's securities market with the approval of the China Securities Regulatory Commission (CSRC).
Chen, Buckland & Williams (2011) use a VECM-MV-GARCH model to test the market structure dynamics of the various industrial sectors of the Hong Kong, Chinese A and B markets in response to regulatory changes. The authors collect sample data that covers a period of 16.5 years from 1st January 1993 to 1st May 2009, which consists of 9 industry series from each of the markets. They report weak evidence of cointegration between the two markets before deregulation in mainland China, but consistently increasing conditional correlations in both long and short-term dynamics among the three markets is found after the implementation of equity market deregulation.

Su & Chong (2007) apply both the Gonzola & Granger (1995)’s permanent–transitory decomposition and Hasbrouck (1995)’s information share methods to examine price discovery between dual-listed Chinese companies on the Hong Kong and New York stock markets. After applying both methods to daily price data of 8 dual-listed Chinese state owned companies from January 1999 to December 2004, among which 2 of the companies are not listed in mainland China, the authors suggest that the stocks from both markets are co-integrated and generally stocks that are listed in Hong Kong are contributing more to price discovery than stocks listed in New York. In addition, they also report that where a company is not listed in mainland China the price discovery contribution would be higher for the New York listed stock compared to those companies which are listed all three markets.

Chen, Li, & Wu (2010) examine the price discovery contributions of cross-listed Chinese stocks based on 16 mainland Chinese stocks that are listed in mainland China, Hong Kong and New York. They collect daily price data between 4th February 1997 and 31st March 2007 for all of the 16 cross listed stocks, but due to restrictions of the issue dates, data length are not the same for every stock. After testing price discovery contributions by looking at the decomposed innovation of the VECM their empirical results suggest that firstly, viewing the mainland Chinese market as a benchmark, the Hong Kong market has a good connection with it, while in the US market these cross-
listed stocks are segmented from the mainland market. Secondly, the US market is
affected by the volatility of mainland Chinese market, but the information flow to the
mainland market tends to be temporary and short lived. And last they report the home
market plays the most important role to price discovery process.

3 Data and Methodology

3.1 Data description

We collect daily price data for 70 dual-listed companies on the Chinese Shanghai and
Hong Kong stock markets. The data sample covers a period from 04/01/2000 to
31/08/2015 with 4,086 observations for each stock, and in total 572,040 observations.
During the 16-year sample period the Chinese government implemented several
regulatory policies that had a significant impact on the behavior of these shares on both
markets. This allows us to examine the connection between government regulatory
policy and dual-listed shares. The 70 dual-listed companies in our sample all originate
in mainland China and most of them have some level of government influence, with a
large proportion of their shares being held by the government. The list of the companies
can be found in Table 1.

[INSERT TABLE 1 ABOUT HERE]

In addition to the dual-listed companies price data we build an additional set of market
level data that consist of the dual-listed A and H indices plus the Hang Seng index. The
market level data is calculated by market value weighted average prices of all A stocks
and all H stocks in our sample respectively. We include the Hang Seng index in the
analysis as a benchmark to capture external factors.
3.2 Methodology

Our initial assumption is the policy makers in mainland China introduce policies based on the needs of the economy. We suggest there is pattern of regulation changes, such that policies switch between contractionary policies (aimed at reducing market openness) and expansionary policies (aimed at attracting investment).

Thus, we first consider the market level connections between policies and their effects on both markets. This will allow us to identify patterns and classify periods as indicated above. Here, we apply price discovery measure. Having obtained the period classifications, we zoom into the company level tests and examine network behavior.

(a) Price Discovery

To examine price discovery, we apply Hasbrouck’s information share to the market level data. Following Hasbrouck (1995), the information share is based on estimation of a Vector Error Correction Model (VECM):

\[ \Delta P_{t,j} = \Pi P_{t,j-1} + \sum_{j=1}^{k} A_j \Delta P_{t,j-1} + e_t \]  

(1)

Where \( P_{t,j} \) is the index price vector. Hasbrouck (1995) decomposes the variance of the common factor innovations and defines the IS of a market as the proportion of variance of the common factor innovations that is attributable to innovations in that market. As shown by Hasbrouck (1995), equation (1) can be then transformed into a vector moving average (VMA) representation as follows:

\[ \Delta P_{t,j} = \Psi(L)e_t = e_t + \theta_1 e_{t-1} + \theta_2 e_{t-2} + \theta_3 e_{t-3} + ... \]  

(2)

The integrated representation of the above VMA is:

\[ P_{t,j} = \Psi(1) \sum_{i=1}^{t} e_i + \Psi'(L)e_t \]  

(3)

The matrix \( \Psi(1) \) in equation (3) is the sum of the moving average coefficients, where
\[ \Psi(1) = I + \theta_1 + \theta_2 + \ldots \], which implies \( \beta^\top\Psi(1) = 0 \). As \( \Psi(1)e_t \) represents the long-run impact of the innovations on the price series, the estimation of \( \Psi(1) \) would be the crucial part for computing the IS measure. By denoting \( \psi = (\psi_1, \psi_2, \ldots, \psi_q) \) as the common row vector in \( \Psi(1) \) and \( \tau \) as a column unit vector, equation (3) can be rewritten as:

\[
P_{t,t} = \tau\psi \sum_{s=1}^{t} e_s + \Psi^\top(L)e_t
\]  

Equation (4) reveals that the price of an index includes two parts, one common factor component \( \tau\psi \sum_{s=1}^{t} e_s \), and the transitory portion \( \Psi^\top(L)e_t \). As Hasbrouck (1995) suggests, the increment of \( \psi e_t \) can be interpreted as the component of the price change which is permanently impounded into security prices, and responsible for reflecting new information. The variance of this term, \( \text{var}(\psi e_t) = \psi \Omega \psi^\top \), is then used to compute the IS measure. Hasbrouck (1995) shows that time series \( j \)'s IS is given by:

\[
IS_j = \frac{\psi_j^2 \Omega_{jj}}{\psi \Omega \psi^\top}
\]  

Applying the Cholesky factorization to the covariance matrix \( \Omega \), such that \( \Omega = FF^\top \), we can rewrite equation (5) as:

\[
\left( \left[ \psi F \right] \right)^2 \quad \frac{1}{\psi \Omega \psi^\top}
\]  

Where \( F \) is a lower triangular matrix with \( F \) of the Cholesky factorization.

With the information share results we are able to examine the impact of market events and government regulation changes on price discovery process in both mainland and Hong Kong markets.

(b) Network Measure
When examining relations using company level data, as the number of companies is large, it becomes hard to interpret these relations with standard models. Therefore, we apply a visualized network method, following Buckle, Chen & Tong (2015), to company level data and build networks on a yearly basis to reveal dynamic behavior.

There are two main types of networks, namely the Minimum Spanning Tree Network (MSTN) and Graphic Network (GN). Both networks are based on correlations of returns, where the correlation values identify the co-movements between every pair of stocks. Daily log returns and standard deviation are calculated as:

\[
R_{C,t} = \ln(P_{C,t}) - \ln(P_{C,t-1})
\]
\[
\sigma_C = \sqrt{\frac{1}{T} \sum_{t=1}^{T} (R_{C,t} - E(R_{C,t}))}
\]

Where

- \( R_{C,t} \) is the return vector of all stocks at time \( t \) and \( E(R_{C,t}) \) is the average value of return;
- \( P_{C,t} \) is the price vector of all stocks at time \( t \);
- \( \sigma_C \) is the standard deviation vector.

Then the correlation between two stocks \( m \) and \( n \) is written as follows:

\[
\rho_{mn} = \frac{\text{Cov}(m,n)}{\sigma_m \sigma_n} \in C
\]

Where \( \rho_{mn} \) is the correlation between stock \( m \) and \( n \);

\( \text{Cov}(m,n) \) is the covariance between stock \( m \) and \( n \);

\( \text{Corr}(C) \) is the correlation matrix containing all correlations in the sample.

There are two key components required in constructing a network: nodes and links. Each node represents a single stock and the links represent how close two stocks are related, and in this case links are based on the price co-movements between two stocks which are represented by the correlation values. With our correlation matrix \( \text{Corr}(I) \),
there are 351-9870⁴ possible links that could be achieved. The key feature of a visualized network is to present information of complex financial network in a simple yet informative fashion. Given such a goal, to examine all possible links would render the exercise cumbersome and uninformative. Therefore, we filter the links to a reasonable number that provides sufficient information while not overcomplicating the network.

As mentioned above there are two types networks and with them two methods to filter the links. The MSTN as the name of the network method suggests, uses the minimum spanning tree method proposed by Gower and Ross (1969) to filter links. This method works by selecting the one smallest link from every node in the network, such that in the end we reach 25-139 links based on number of included stocks. The GN filters links by selecting a percentage of the highest correlations from all possible links, which is usually from 5%-20% depending on the size of the network. In this case, as the networks are not very small we use 10%; which results in 35-987 links in each of the graph networks.

While the GN filter method is relatively straightforward, for the MSTN it requires further modification to the raw correlations. One common method is the Gower-distance measure (Mantegna, 1999), which takes higher correlations to represent shorter links as follows:

\[
D(C) = \sqrt{2(1-Corr(C))}
\]  

(9)

Where \(D(C)\) is the inter-market distance measure and \(0 \leq D(C) \leq 2\). This method possesses several advantages in forming a correlation based MSTN, 1) All correlation values are assigned a non-negative value; 2) large correlations, which indicate a higher significant level of connections between nodes than small ones, are reflected as shorter links in the network structure; 3) Gower-distance values are suitable for applying the

⁴There are 351 correlation values we can get in 2000 as there are only 26 stocks included, by 2013 there are 140 stocks and the number of correlations increase to 9870. Possible links refer to maximum number of correlations we can get.
“minimum spanning tree” (MST) procedure and more meaningful to be used as links in networks.

The next step in applying the MST is to select the most important and meaningful links, this is done in several steps:

(1) For each node, collects all distance values to the rest of the network and save as ‘distance set’ for the node, and then select the shortest one from each distance set.

(2) During the selection process for the entire network, if multiple pairs of two nodes happen to have selected the same shortest links (e.g. For node H1, the H1 to A1 link is the shortest distance and for node A1, the A1 to H1 link is the shortest; and similar situations are found for H2 and A2, and H3 and A3 etc), we need to compare these links and find the longest one (e.g. we compare H1 to A1, H2 to A2 and H3 to A3), temporarily keep the longest link, say H3 to A3 and proceed to the next step;

(3) Now deal with the other pairs of nodes that have selected the same links. Take node H1 and node A1 as an example; we now need to pick the second shortest distance in their distance sets. Node H1’s second shortest link is H1 to H2 (with value of 1.2) and node A1’s second shortest link is A1 to A2 (with value of 0.9). We apply the basic minimum spanning tree principle of the shortest distance and keep the A1 to A2 link; subsequently, this will be assigned to node A1. For node H1, because H1 to H2 link is the longer one between the two (1.2 vs. 0.9), we don’t keep it; therefore, node H1 will go back to keep the H1 to A1 link.

This procedure is repeated for all other pairs of nodes that have the same selected links.

(4) After clearing all the duplicated links, we put back the link we temporarily kept in step (2) to the network. Then repeat steps (2) and (3) until there is only one pair of nodes that have selected the same link, and delete either one of the duplicated links.

After the MST process we obtain a vector of ‘significant’ correlations \( \hat{Corr}(C) \), and for a company, \( m \), we denote that vector of ‘significant’ correlations as \( \hat{Corr}(m) \). The
correlations in $\hat{Cor}(C)$ are used as links to build the MSTN and the length of them are decided by the Gower-distance values of these correlations.

To make networks more informative, we assign node sizes in both types of networks, this allows us to comprehend the structure of networks. For MSTN we let node sizes represent importance coefficients which relate to the market values of each stock and connectivity level. For connectivity level, we set a threshold $\bar{\rho}_{MST}$ and for every stock we count the number of correlations that are above this threshold. $\bar{\rho}_{MST}$ is the average of correlations of all links that are included in a MSTN and can be subsequently written as:

$$Threshold = \bar{\rho}_{MST} = E[\hat{Cor}(C)]$$

and

$$S_m = 1, ..., N - 1, \forall \hat{Cor}(m) \geq \bar{\rho}_{MST}$$

Where $S_m$ is the connectivity level of stock $m$.

For the market value part, we use a stocks relative market value ($MV_m$) to the total market value of all stocks, which can be written as follows.

$$RMV_m = \frac{MV_m}{\sum_m MV_m}$$

By combining the two components we achieve the importance coefficient (IC) and the importance coefficient of a stock $m$ can be represented as

$$IC_m = S_m * RMV_m$$

For GN the sizes of node is represented by the clustering coefficient (CC), which is calculated by counting the number of links a node has in a GN.

A summary of the nodes and links used in the construction of MSTN and GN is set out in Table 2.
4 Empirical results

The main purpose of this paper is to identify the long-run dynamic co-movements between company shares that are dual listed in the Shanghai and Hong Kong markets. We also investigate changes in stock price behavior in relation to major policy changes implemented by the Chinese government at both a market and company level. Also, given the difference in regulations between the Hong Kong and Shanghai markets, it is of interest to examine the connections between a company’s shares in the two markets as well as their relations with other (non-dual listed) shares in the same market. Market level behavior is examined using a price discovery measure using two indices that are constructed from dual listed A and H shares plus the benchmark Hang Seng index. In summary of the forthcoming results, we find a general indication that A shares become more important in the price discovery process when the Chinese government loosens regulations. Also at times of regulation changes involving a reduction of state control shares, A shares appears to contribute more to the price discovery process, although based on the information share (IS) results, H shares always lead the price discovery process compared with A shares. At the company level, we use a combination of Graph and MST networks. We find, instead of connections between corresponding dual-listed shares of a company, the connections within a market (e.g. one A share to another share) are stronger. We also find that, in general H shares are more inter-connected with each other than A shares. In addition, changes in regulation appear to have a strong impact on the behavior of these dual listed shares.

4.1 Price Discovery Results

Table 2 shows that the benchmark Hang Seng index contributes the most to the price discovery process throughout the 16 years. The mechanism of the IS method is to
examine price changes in relation to underlying information of all indices which are included in the test. The Hang Seng index is a large international market index and liquidity is much higher in the Hong Kong market and therefore it is not surprising to see this index leads the A and H indices in terms of price discovery. After the Hang Seng index, the highest price discovery contributions come from the H index and the contributions increase with time. This could be caused by more companies being included in the H index pool with time.

[INSERT TABLE 3 ABOUT HERE]

The Hang Seng index as a benchmark in the price discovery test is there to account for external (global) factors. Hence, we also focus on results from A and H indices alone, given in columns 6 and 7 of Table 3. Although the A index is never higher than the H index in price discovery contribution throughout the sample period, there is some volatility in the price discovery contributions over the sample period. Based on the price discovery result changes, we classify the sample period into several sub-periods, 2000-2001 (P1), 2002-2003 (P2), 2004 (P3), 2005-2006 (P4), 2007 (P5), 2008-2009 (P6), 2010-2013 (P7) and 2014-2015 (P8). The changes in price discovery for these sub-periods are then related to regulation changes. In summary, we find a clear connection between the price discovery results and selected Chinese government policies. The policies are set out in Table 4. When regulations are designed to open up the mainland market or increase economic relations between Hong Kong and mainland, the importance of H shares appears to increase, like 2002, 2004, 2007 and 2010. On the other hand, when regulations are aimed at reducing control in the mainland market, A shares would be more active and have comparable higher price discovery contribution, like 2001, 2005 and 2015. Although there is a lot of turbulence in terms of price discovery contribution during the sample period, dual-listed H shares are always

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5 The proportional results are calculated from price discovery results between A and H indices in table 3. By normalize them to a sum of 100%.
leading the price discovery of dual-listed A shares.

During P1 both A and H indices appear to have very low price discovery contribution, and this could be explained by the fact that the number of companies in A and H indices is low (below 20), which may not show as much sensitivity to information compared to the Hang Seng index. In this period except for 2001, the A index shows no price discovery contribution at all. In 2001, the price discovery results jump from 0% to 0.62% and from 0.03% to 26.75% in the proportional IS results. A possible reason for this dramatic movement is a change in Chinese government’s policy in June 2001 which allowed state-held share to be converted and made available for trade in the market. Although this policy was withdrawn in October due to negative performance in the A market, it made the Chinese mainland market less restricted and allowed the mainland market to be more receptive to information. So in this year the A index reflects as a higher price discovery contribution in the IS analysis.

A notable Chinese government policy during P2 is the Qualified Foreign Institutional Investor (QFII) scheme introduced in November 2002. This scheme opened the Chinese A market to international investors. This scheme not only opened up the A market but also increased convertibility between dual-listed A and H shares and helped spur capital flows into the Hong Kong market and especially those dual-listed H shares (Fergusson & McGuinness, 2004; Peng, Miao & Chow, 2008). Such effects increase the price adjustments in the H index in 2002 and 2003. The price discovery results of the H index increase significantly compared to previous years, from 1.69% up to 8.22% in 2003.

During P3 the Chinese government introduced an agreement called the Closer Economic Partnership Agreement (CEPA) to increase the economic connection with Hong Kong. This agreement allows Hong Kong Banks to offer RMB deposit-taking services in Hong Kong. This policy greatly increased capital flows to Hong Kong (Cai, McGuinness & Zhang, 2011). At the same time, the mainland market was suffering a
market crash,\textsuperscript{6} which led to a loss of investor confidence in the market. Together these two developments induced investment in the dual-listed mainland companies but mainly though the Hong Kong listing. This explains the large boost in the H index price discovery results.

In 2005 the Chinese government introduced a ‘pilot scheme’ for the ‘split share reform’ program. In the China mainland market, listed companies’ shares was divided into regular tradable shares and non-tradable shares; usually 2/3 of the companies’ shares are non-tradable. The ‘split share reform’ program was aimed at increasing the amount of public tradable shares. This scheme reduces government control on the A share market and therefore A shares prices are more affected by market information. The IS results in P4 support this as we find an increase in dual-listed A shares price discovery contribution, from 0.38% to 2.32% and 1.75% to 30.82% in the proportional IS results. There was a slight decrease of dual-listed A shares IS results by the end of P4 in 2006, but the contribution is still much higher than previous and later periods.

During P5, the Chinese government established phase 2 of the QFII program. As we explained earlier, QFII is aimed at increasing capital flow to dual-listed H shares, so in this period we find an increase in the H index price discovery results from 2.2% in 2006 to 14.84% in 2007.

P6 is a quite different period where the world was facing a financial crisis. In this period we find the IS results of the Hang Seng index was greatly reduced, which reflects the fact that open markets are affected by the financial crisis. On the other hand, the underlying companies of dual-listed shares were supported by the Chinese government as during this period the government not only introduced policies to prevent a crash in the mainland stock market but also invested 4 trillion RMB to help large companies.

\textsuperscript{6} In the beginning of 2004 announced nine policies to spur the mainland market, which induced a bull market for a period. However, in March 2004 this bull market
For this reason, we find an increase in price discovery in both dual-listed A and H indices, but such an increase should be viewed in the context of the weak global performance, rather than an increase in importance of A and H shares.

At the start of P7 in 2010, the Chinese government reduced restrictions on mainland investors and allowed them to trade foreign currency on Hong Kong markets through exchange broker agencies under commercial banks. During P7 we find a general increase in price discovery in both the Hang Seng index and H index from 52.32% to 54.13% for Hang Seng index and from 36.19% to 39.21% for the H index. This, we argue, is caused by this boost of capital flows from mainland China to Hong Kong.

In more period P8, by late 2014 the Chinese government introduced several policies to reduce the IPO barrier and simplify the process of an IPO in the A market. The resulting increase in capital flow to the A market appears to have boosted activity in the A market and this is reflected in the price discovery results, with an increase in the dual-listed A share IS results from 5.74% in 2014 to 8.61% in 2015.

[INSERT TABLE 4 ABOUT HERE]

4.2 Network Results

Network results are able to provide a visualized and dynamic pattern of connections among the dual-listed shares. We applied both MST Network and Graph Network, where MST network captures the structure of linkages among the dual-listed shares and Graph network provides information on clustering effect in terms of how clusters form and how clusters are linked with each other. In general, from both the MSTN and GN we find the linkages between dual-listed A and H shares are usually weaker than inter-connections between A shares or H shares, which indicates that dual-listed A and H shares are more affected by market specific information rather than company-specific
information. Such connection patterns are quite unique, as dual-listed shares in two less regulated markets are usually linked with high correlation (see Bedi, Richards & Tennant, 2003).

In the GN results, we find a general tendency for dual-listed shares to move closer to each other with time. As Figures 1, 2 & 3 shows before the year of 2005 we are able to identify clearly two cluster groups of A shares and H shares and even in 2005 as shown in Figure 4 there is only a weak link between the A cluster and H cluster with only one link that connects them. In more recent years such as 2014 and 2015, see Figure 8, the A and H clusters have clearly merged together with multiple links between them. The MSTN results also support the finding of the tendency of dual-listed shares moving closer to each other with time. In addition, in the early years before 2005 both A and H shares are linked only with other shares that are listed in the same market which forms clearly two groups of shares by the markets they are listed in. After the year of 2005 we begin to see some shares begin to link with their corresponding dual listed shares so that by 2015 there are 12 shares found to be linked with their corresponding dual listed shares.

We follow the period classification used above in the price discovery analysis and examine whether the network results are related to the policy changes implemented by the Chinese government. Generally, the network results are in line with the regulation changes. We find when policies are helping increase mainland market activities the inter-connections between A shares are increased and are stronger than H shares. In addition, policies that help increase capital flows to dual-listed H shares, are related to increased connectivity between H shares as well as greater connectivity between A and H shares.

In P1, the dual-listed H shares are more closely connected with each other than dual-listed A shares in the MSTN. We can also see the cluster of H shares is larger than A shares in the GN, but the size of nodes of A shares are much larger than H shares in the
MSTN. This is because the dual-listed companies usually have a larger market capitalization in the mainland market compared to the Hong Kong market. During this period, in the MSTN, we can see the linkage between the A and H market is much shorter (closer) in 2001 than 2000. If we compare P1 with P2 we still find 2001 having the closest linkage. This is likely to be a consequence of the Chinese government allowing state-held shares to be converted and made available for the market in 2001 for four months. This increased the market activity in the A market and helped the dual-listed A shares to be more closely related with their corresponding H shares.

During P2, due to the initiation of the QFII scheme we can see a complete reversal of the pattern from P1. A shares form a larger cluster compared to H shares in the GN and also A shares are more closed linked with each other in the MSTN. The QFII opened up the Chinese mainland market to foreign investors and capital flows (i.e. to the A share market). Usually when capital inflows increase into a market the market will become more integrated. (Chelley-Steeley, 2005; Chen, Firth, & Rui, 2002)

In P3 there is a slight reversal of the pattern in both the MSTN and GN and we see again H shares becoming more closely linked with each other compared to A shares. We also observe an increase in the linkage between A and H share groups and this is likely to be due to the ECPA scheme introduced in 2004 which increased capital flows from mainland China to Hong Kong. In P4 and P5, the general pattern of networks revert back to be similar to those in P2, and there is another jump in the strength of linkage between A and H groups. The reason for this is likely to be the share split reforms in 2005 and phase II of the QFII scheme in 2007 that affected the mainland market in the same way as in P2.
P6 is the period of the global financial crisis. Surprisingly we find a ‘big jump’ in connections between A and H shares in the 2008 MSTN. This time the ‘jump’ is unlikely to have been caused by a loosening of A market regulations, and during this year the Chinese government enhanced market control to prevent the A market from collapse. The reason for the increase in strength of linkages between the A and H markets in 2008 is likely to be because during the crisis markets would tend to move away from the centre of the crisis and become closer to markets that are less affected by the crisis and in this circumstance it is the A market. (see Buckle, Chen & Tong, 2015). Another reason for this result could be our network is capturing the share performance of the whole year and the crisis only happened in the middle of the year, and so the performance in the first half year may offset some effects of the crisis. In 2009, we can see the connections between A shares and H shares break apart, and became two separate clusters like those in P1 and P2.

In the beginning of P7, to help the Hong Kong market to recover from the crisis, the Chinese government allowed mainland investors to invest in the Hong Kong market. As a consequence of this policy we can clearly see the link between A and H shares begin recovering from the crisis, and in the GN the A and H markets were back to one cluster by 2012.

[INSERT FIGURES 6 & 7 ABOUT HERE]

In the most recent years in the sample, P8, by late 2014 the Chinese government released several policies to reduce the barriers to IPO activity and simplify the process of an IPO in the A market. This greatly increased capital flows into the A market and boosted market activities. In both the MSTN and GN, we can observe a clear indication that both A and H shares are again becoming highly connected.

[INSERT FIGURE 8 ABOUT HERE]
Besides the visualized networks, we also record, in Figure 9, the thresholds used in the MSTN, which are the average of the highest correlation from every node in the network. These threshold figures support our visualized network results, in that we see a general trend of the thresholds to increase with time, which suggests the overall correlations are increased overtime. Also we can observe the linkage between the two markets is becoming closer over time with an increase from 0.157 in 2000 to 0.72 in 2015. In addition, all of the big jumps in the linkage values occur at the times when government regulations relax controls in the A market such as in 2001, 2005, 2007, 2010 and 2015. [INSERT FIGURE 9 ABOUT HERE]

4.5 Conclusion

In this paper we apply two methods, namely the price discovery measure and the network measure, to examine the relations between dual-listed Chinese stocks on the Shanghai and Hong Kong markets. Additionally, we look at the impact of polices in mainland China on both markets. Our results support past literature that the dual-listed shares become more integrated over time. Additionally, we report that every sharp change in linkage between A and H shares, either more integrated or otherwise, is related to the announcement of a new policy by the Chinese government. We provide clear evidence that regulation changes in mainland China affect the performance of not only the mainland market itself but also the dual-listed H shares, and as the number of dual-listed stocks increase these mainland market policies also appear to affect the Hong Kong market itself to a certain extent.

We find a clear connection between price discovery contributions in both markets and Chinese government policies. When regulations are aimed at opening up the mainland market or increasing economic relations between Hong Kong and mainland China, dual-listed H shares benefit greatly. In contrast, when policies are aimed at reducing control in mainland China, dual-listed A shares are more active and have comparable
higher price discovery contribution. From our network results we find that when policies help to increase mainland market activities the inter-connections between A shares are boosted compared to H shares. For policies that are aimed at increasing capital flows to dual-listed H shares, not only are H shares inter-connection increased but also the connection between A and H shares increase.

WHAT DO THE RESULTS MEAN!

References


Table 1: Data summary. This table summarizes the exchange share codes of dual-listed Chinese A and H shares. We also give each A and H shares of each dual-listed firm node names that appear in our visualized networks.

<table>
<thead>
<tr>
<th>Name of Company</th>
<th>Share Code .HK</th>
<th>.SH</th>
<th>Node Names H A</th>
<th>Name of Company</th>
<th>Share Code .HK</th>
<th>.SH</th>
<th>Node Names H A</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Tractor</td>
<td>0038 601038</td>
<td></td>
<td>H66 A66</td>
<td>China Shenhua Energy Company Limited</td>
<td>1088 601088</td>
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<td>H37 A37</td>
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<td>Sichuan Expressway Co Ltd</td>
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<td></td>
<td>H55 A55</td>
<td>China National Medicines Corporation Ltd</td>
<td>1099 600511</td>
<td></td>
<td>H52 A52</td>
</tr>
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<td>Luoyang Glass Co Ltd.</td>
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<td>China Shipping Development Co Ltd</td>
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<td>1171 600188</td>
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<td>H11 A11</td>
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<td>A3</td>
<td>China Railway Construction Corp Limited</td>
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<td>A4</td>
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<td>New Cn Life Ins</td>
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<td>A6</td>
<td>China Life Insurance Company Limited</td>
<td>1339 601628</td>
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<td>H65 A65</td>
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**Table 2: MSTN and GN Construction Description.** This table explains the meaning of components (Nodes and Links) that form a MSTN or GN. We also give interpretation of the basic features of these network components.

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<thead>
<tr>
<th>Component</th>
<th>MSTN</th>
<th>GN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodes</td>
<td>Stocks</td>
<td></td>
</tr>
<tr>
<td>Links</td>
<td>Correlations between two linked stocks</td>
<td>n/a</td>
</tr>
<tr>
<td>Length of Links</td>
<td>Gower-distance of correlation</td>
<td>n/a</td>
</tr>
<tr>
<td>Size of Nodes</td>
<td>Importance coefficient</td>
<td>Clustering coefficient</td>
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</table>
Table 3: Period Classification with Market Events Timeline. This table presents a period classification of our sample period and these periods are classified following a timeline of major market events such as deregulation in both A and H share markets. The major results are also briefly reported to match each period.

<table>
<thead>
<tr>
<th>Periods</th>
<th>Price Discovery Results Summary</th>
<th>Government Regulation Changes and Market Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 2000~2001</td>
<td>Both A and H indices play non-significant price discovery, which means that neither share issuance dominates the price movements in the other. A share index started to appear price dominance in 2001 in response to temporary sale of state shares.</td>
<td>Permission of state-held shares to be converted and made available for sale on the A share market in July 2001 but quickly suspended in October due to poor market performance.</td>
</tr>
<tr>
<td>P2 2002~2003</td>
<td>A large boost in H index price discovery contribution. Proportionally, A index offers to contribution to price discovery.</td>
<td>Official announcement of Qualified Foreign Institutional Investor Scheme (QFII), that opened up the Chinese A market to qualified foreign institutional investors.</td>
</tr>
<tr>
<td>P3 2004</td>
<td>A large boost in H index price discovery contribution. Proportionally, A index offers to contribution to price discovery.</td>
<td>Establishment of Closer Economic Partnership Agreement (CEPA), in early 2004, which enables Hong Kong banks to offer RMB deposit services in Hong Kong.</td>
</tr>
<tr>
<td>P4 2005~2006</td>
<td>Both A and H indices price discovery levels dropped.</td>
<td>The government launched a 'Pilot Scheme' for the ‘Share Split Reform' to re-sell non-tradable A shares, that amounted 2/3 of the concurrent market capitalization of the entire A share market.</td>
</tr>
<tr>
<td>P5 2007</td>
<td>A boost in H index price discovery</td>
<td>CSRC began the second phase of the QFII scheme initiated in 2002. The 'Through Train' initiative was initiated to allow the Tianjin-based clients of Bank of China to directly invest in the Hong Kong market.</td>
</tr>
<tr>
<td>P6 2008~2009</td>
<td>Significant increase of price discovery level in both A and H Indices.</td>
<td>The Chinese government introduced 9 strict policies and also invested 4 trillion RMB to the mainland market to prevent market crash in the midst of the 2008 financial crisis.</td>
</tr>
<tr>
<td>P7 2010~2013</td>
<td>Proportionally, A index demonstrated stronger price dominance over H index.</td>
<td>CSRC deregulated the investment constraints for mainland Chinese investors to trade on the Hong Kong market with foreign currency through exchange broker agencies.</td>
</tr>
<tr>
<td>P8 2014~2015</td>
<td>Both A and H indices appear to contribute to price discovery while the A share index show slight dominance.</td>
<td>By late 2014 Chinese government released several policies to reduce IPO barrier and simplify the process in the A share market. However, this was proved to be ineffective in mid 2015.</td>
</tr>
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</table>
Table 4: Price discovery results. This table reports the price discovery results of both Information Share for three comparable indices: dual-listed A share index, dual-listed H index and Hang Seng Index. It also provides the results of the Proportional IS method on the A/H index. The construction of dual-listed A/H index is based on a price weighted average method over the entire dual-listed A/H shares.

<table>
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<th>Year</th>
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<th>Proportional IS Year</th>
<th>Proportional IS Period</th>
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<td>HS</td>
<td>A</td>
<td>H</td>
<td>A</td>
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<td>1.58%</td>
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<td>2001</td>
<td>97.69%</td>
<td>0.62%</td>
<td>1.69%</td>
<td>26.75%</td>
<td>73.25%</td>
</tr>
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<td>2002</td>
<td>P2</td>
<td>94.06%</td>
<td>0.00%</td>
<td>5.94%</td>
<td>0.01%</td>
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<td>2003</td>
<td>91.68%</td>
<td>0.09%</td>
<td>8.22%</td>
<td>1.14%</td>
<td>98.86%</td>
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<td>2004</td>
<td>P3</td>
<td>78.05%</td>
<td>0.38%</td>
<td>21.56%</td>
<td>1.75%</td>
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<td>2005</td>
<td>P4</td>
<td>92.49%</td>
<td>2.32%</td>
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<td>8.61%</td>
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Figure 1: MSTN and GN constructions by periods. This figure presents the MSTN and GN constructions organized in periods as described in Table 3. We can clearly observe the changes in the A and H clustering and importance of individual firms as they continue to operate in time. For example, one distinct change is that the A and H clusters started to connect to each other since 2005, which could be due to higher level of trading activities and accumulative effects of series of regulatory changes since 2000.
**Figure 9: Threshold for MSTN.** This figure provides both visual and numerical expressions of the threshold that are the averages of the highest correlation from each node in the minimum spanning tree network.

![Graph showing threshold for MSTN with years from 2000 to 2015 and corresponding values for G, H, A, and Link.](image-url)

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