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Determining the contributions to price discovery for Chinese cross-listed stocks ☆

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Abstract

We study the price-discovery process for a number of Chinese cross-listed stocks. For the stocks cross-listed on the New York Stock Exchange (NYSE) and the Stock Exchange of Hong Kong (SEHK), we find that the stock prices of these two exchanges are cointegrated and mutually adjusting, and that the SEHK makes more contributions than the NYSE to the price-discovery process. The SEHK contributions are 81.6% and 89.4%, computed from Gonzalo and Granger [Gonzalo, J., Granger, C., 1995. Estimation of common long-memory components in cointegrated systems. Journal of Business and Economics Statistics 13, 27–35] permanent–transitory (PT) and Hasbrouck [Hasbrouck, J., 1995. One security, many markets: Determining the contributions to price discovery. Journal of Finance 50, 1175–1119] information share (IS) models respectively.

JEL classification: G14; G15
Keywords: Price discovery; H share; Information share; Permanent–transitory model

1. Introduction

The last decade has witnessed an increasing globalization of the world financial markets. This increase has led to global presence of international cross-listing activities. When a stock is listed and traded in more than one market, the behavior of the prices in each market is worth examining. Since the stock prices are based on the same underlying asset, they should be the same across markets due to the law of one price. However, because of the existence of noise, the price of the same stock may deviate across markets. As a temporary price difference creates an arbitrage

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opportunity, the arbitrage activities will keep the price in each market from drifting away from the implicit efficient price (Baillie et al., 2002). The implicit efficient price is determined by the news that affects the prices of all market permanently. The search for this implicit efficient price is the price-discovery process.[1]

The contribution to the price discovery of different markets is first studied by Garbade and Silber (1979) with dually listed stocks within the United States. They test whether the dually listed equities on the New York Stock Exchange and regional stock exchanges share a common equilibrium price. They introduce the dominant and satellite markets and find that the NYSE performs like a dominant market. Harris et al. (1995) examine the relative contribution of the NYSE and regional exchanges to the price discovery for the IBM. In recent years, the number of American Depository Receipts (ADRs) and Global Depository Receipts (GDRs) issues has increased rapidly. As a result, the price-discovery contribution of foreign exchange to individual stocks has been receiving attention. Pascual et al. (2001) analyze five Spanish stocks cross-listed on the NYSE during the daily 2-hour trading overlap of both exchanges. They calculate the Hasbrouck (1995) information share, and find that the NYSE contribution to the price discovery only varies from 1% to 3%. Eun and Sabherwal (2003) study the contribution of the U.S. stock exchange to the price discovery for 62 Canadian firms listed on the Toronto Stock Exchange (TSE) and one of the U.S. exchanges. They find that the average U.S. share of contribution is 38.1%. It is shown that the U.S. share of price discovery is directly related to the U.S. share of trading volume and informative trades, and inversely related to the ratio of bid–ask spreads. Grammig et al. (2005) study the contributions of the Frankfurt and the New York Stock Exchange for three German stocks with high frequency quotes. They report that the bulk of price discovery during the overlapping period occurs in the German market.

Most of the aforementioned studies focus on developed markets. The studies on price discovery for stocks from emerging markets cross-listed on developed markets are limited. This is mainly due to the unavailability of high quality intraday data. Kadapakkam et al. (2003) examine the Indian stocks dually listed on the London Stock Exchange as Global Depositary Receipts (GDRs). They use the daily opening and closing prices to compute the information share of the London and Mumbai markets. It is found that the two markets contribute almost equally to the price-discovery process. They conclude that GDRs' market's contribution to price discovery increases with the foreign institutional investment of the firm and the size of the GDRs issue.

Ding et al. (1999) investigate price discovery of a large Malaysian conglomerate traded both in Kuala Lumpur Stock Exchange (KLSE) and the Stock Exchange of Singapore (SES). Using the Gonzalo and Granger (1995) common long-memory factors, they find that nearly 70% of the price discovery occurs in the home country and that 26–32% can be attributed to the SES.

Over the last decade, we have witnessed an increasing number of Chinese firms listing abroad. As a result, the cross-listing of Chinese companies has recently become a popular research topic. Wang and Jiang (2004) examine a group of stocks cross-listed on the Mainland exchanges as A share, and on the Stock Exchange of Hong Kong as H share. They find that A-share returns are subject to the risk and investor sentiment that is specific to the Mainland stock markets. However, H-share returns are subject to the market-specific risk and investor sentiment in both the Hong Kong and Mainland stock markets. In addition, they find that the price discount of H share relative to A share is highly correlated with the domestic and foreign stock market indices and the relative market illiquidity. They also show that H-share price discount is positively correlated with the expected devaluation of the Chinese currency.

[1] According to Schreiber and Schwartz (1986), price discovery is the key function of a stock exchange.

Xu and Fung (2002) examine the China-backed stocks that are cross-listed on the Stock Exchange of Hong Kong and the New York Stock Exchange. They study the information transmission between the two markets via a bivariate generalized autoregressive conditional heteroskedasticity (GARCH) model. The empirical results indicate that there is a significant mutual feedback of information between the two markets in terms of pricing and volatility. Stocks listed on the Hong Kong exchange appear to play a more significant role of information transmission in the pricing process, while stocks listed on the NYSE play a bigger role in volatility spillover.

According to the statistics of the SEHK, the market capitalization of the China-related stock in the Main Board is less than 5% of the total market capitalization in 1993. As of 2005, this figure has risen to 37%. These China-backed companies include those with the world largest IPOs such as the China Life Insurance Co. and the China Construction Bank. Despite its potential importance, the issue of where price discovery occurs for cross-listed Chinese stocks is surprisingly understudied. In light of this, we examine the price discovery of eight Chinese stocks that are cross-listed on the Stock Exchange of Hong Kong and the New York Stock Exchange. These eight firms are listed as American Depository Receipts (ADRs) on the NYSE. Since the ADRs can be freely converted to H share, the arbitrage forces equalize the prices in the NYSE and the SEHK. We find that the two prices are cointegrated with one common factor. We use two models, Hasbrouck (1995), and Gonzalo and Granger (1995) models, to compute each market's price-discovery contribution. The empirical results obtained from the two models are quite similar. We find that the SEHK contributes more to the price-discovery process than the NYSE for these eight China-backed stocks. It is also found that the NYSE contributes more if the stock is not listed on the Shanghai Stock Exchange or the Shenzhen Exchange.

The paper is organized as follows: Section 2 provides a brief overview of Chinese firms' overseas listing. Section 3 investigates the price-discovery process of China-backed stocks cross-listed on the SEHK and the NYSE. Section 4 concludes the paper.

2. Overseas listing of Chinese firms

Since the establishment of the Shanghai Stock Exchange and the Shenzhen Exchange in the early 1990s, the Chinese equity market has expanded quickly. As of the end of December 2003, there are 1285 companies listed on the Shanghai Stock Exchange and the Shenzhen Exchange with a total market capitalization of 4274.9 billion RMB, which is 390 times the 1991 market value. Although the Chinese equity market has developed rapidly, it cannot satisfy the huge demand for capital arising from the rapid growth of the economy. China-backed companies began to list abroad in the early 1970's, mainly in Hong Kong. According to the statistics of the SEHK, there were eight China-backed companies listed in the 1970's and eight in the 1980's. These companies are usually incorporated outside China and listed on the SEHK by direct IPO or by acquiring a listed company to go public indirectly. In recent years, many non-government background companies, such as China Mobile (Hong Kong) and Levono, are also incorporated in this way and list their shares on the SEHK.

The Chinese-backed companies are often called Red Chips. As of the end of 2004, 81 Red Chip companies have been listed on the Main Board of the SEHK and its market capitalization has reached 21.26% of the total market capitalization of the Main Board. Similar to the Red Chips in the SEHK, a number of Chinese firms have registered a listing vehicle and listed on the NASDAQ, Singapore, Toronto, and Australia stock exchanges.

In 1993, Chinese state-owned enterprises (SOE) started to issue shares in Hong Kong. A number of large SOEs, such as the Tsingtao brewery, SINOPEC and Huangneng Power, have entered the stage of the international equity market. They were featured as the market leaders of each industry in China. Some of those companies are listed on the New York Stock Exchange in the form of American Depository Receipts. According to the statistics of the China Securities and Regulatory Commission (CSRC), as of the end of November 2004, there are 107 companies listed overseas, 106 of which have issued shares in the SEHK.

The international listing of Chinese companies is different from its counterparts in that most of the non-Chinese companies have already issued shares in their domestic equity market before listing their shares on a foreign exchange, while none of the Chinese firms has issued shares in the home stock market before the international listing. As of the end of 2003, there are 29 firms cross-listed on the domestic exchanges and the SEHK, all of which have issued H shares prior to their A share's listings. The different sequence of the listing indicates that there are different motivations for Chinese companies to list abroad.

The first and foremost motivation is to raise a large amount long-term capital for future growth. Although the Chinese equity market has developed rapidly, it cannot satisfy the growing demand of capital. Owing to the premature nature of the Chinese stock market, there is fear that the equity market will collapse if too much capital is to be raised domestically.[2] For this reason, a number of big Chinese enterprises have chosen to list abroad.

The second motivation of overseas listing is to improve the corporate governance of the large state-owned enterprises. In spite of the expensive cost of listing, as well as the stricter requirement of disclosure compared with the China equity market, some of the Chinese companies still choose to list abroad. Compliance with these requirements enables the listing firms to establish a good corporate structure and modern corporate governance.[3]

The third motivation for listing abroad is to build an international image and to gain visibility in the global market. Raising capital from the global equity market is a necessary step for firms to expand their business overseas. Information disclosure and analyst coverage accompanied by a listing will make the Chinese firms better known by potential foreign partners and clients. For instance, Air China lists on the London Stock Exchange because the company's international business focuses on Europe.

3. Data and the model

In this section, we investigate the relative contribution of the SEHK and the NYSE to the price-discovery process for cross-listed China-backed stocks.

3.1. Data

Previous studies on the price discovery across the developed countries (Eun and Sabherwal, 2003; Grammig et al., 2005; Pascual et al., 2001; Ding et al., 1999) use high frequency data to ensure the simultaneity of observed price across markets. These studies can be done because there is an overlapping trading period between the two markets and because the high frequency data are available. When there is no overlapping trading period, one can only rely on low-frequency data. Lieberman et al. (1999) examine the price behavior of six firms dual-listing their stocks in Israel

[2] For instance, China mobile (HK) has raised 145.9 billion RMB from Hong Kong and the U.S. market in 1997, which is 17% of the market value of all tradable shares in Shanghai Stock Exchange in 2003, and is more than twice the total capital raised for A share in Shanghai Stock exchange in 2003.

[3] The early large state-owned enterprises' overseas listings were prompted by the government for this reason.

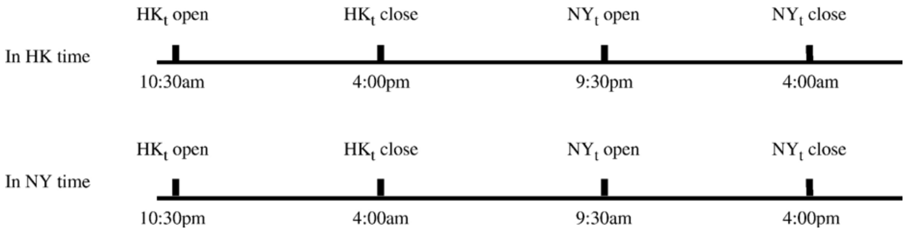

Fig. 1. Trading hours of the SEHK and NYSE.

and the U.S. with daily closing prices. They find that the prices in different markets are cointegrated, and arbitrage opportunities are generally not available. They also demonstrate that the effect of Israeli market on the share prices in the U.S. is stronger than the reverse direction. Kadapakkam et al. (2003) apply the price-discovery method to non-synchronous closing prices of the London and Mumbai markets and find that the two markets contribute almost equally to the price discovery.

In our study, we use daily data since there are no overlapping trading hours between the NYSE and the SEHK. Fig. 1 presents the relative timing of trading hours of the NYSE and the SEHK. Hong Kong standard time is 12 h ahead of New York. The SEHK begins trading at 10:00 am and closes at 4:00 pm in local time. The trading hours of the NYSE are from 9:30 am to 4:00 pm in local time, which is 9:30 pm to 4:00 am in Hong Kong time. Therefore, there are no overlapping trading hours.

According to the statistics of China Securities Regulatory Commission, as of the end of November 2004, there are 17 Chinese firms listed on the New York Stock Exchange, five on the London Stock Exchange, one on the Stock Exchange of Singapore, and 106 on the Stock Exchange of Hong Kong. Some of the Chinese firms are listed on more than one overseas exchange, and the majority of these firms are cross-listed on the SEHK and the NYSE. In total, there are 12 Chinese firms cross-listed on the SEHK and the NYSE at the end of 2004. To ensure a minimum sample period of 5 years, companies that listed after December 31, 1998 are excluded. The sample size is reduced to eight firms after the imposition of this restriction. The basic information of these eight firms is reported in Table 1.

The daily closing prices of H shares and ADRs in HK dollars are extracted directly from the Datastream. Using the conversion ratios (number of Hong Kong shares that is equivalent to one share of ADRs), we convert the ADRs price to Hong Kong dollar price per share so that the ADRs prices and H-share prices are comparable.

3.2. Methodology

We adapt two popular common factor models to investigate the mechanics of price discovery: the Permanent–transitory (PT) model of Gonzalo and Granger (1995) and the Information Shares (IS) model of Hasbrouck (1995).[4] Both models are based on the vector error–correction model (VECM). The PT model of Gonzalo and Granger (1995) focuses on the error–correction process. It measures each market's contribution to this common factor and the contribution is the function of the markets' error–correction coefficients. The IS model of Hasbrouck (1995) defines price

[4] So and Tse (2004) also use the two models to investigate the price discovery among the Hang Seng Index markets with minute-by-minute data. They show that the Hang Seng Index, Hang Seng Index futures and the Tracker Fund have different degrees of information processing abilities, despite that fact that they are governed by the same set of fundamentals.

Table 1
China-backed companies cross-listed in Hong Kong and New York

Company name	SEHK code	NYSE ticker	Industry	Sector	SEHK listing date	NYSE listing date	Data base date	Conversion ratio	Initial ADR size in billion HKD	Mkt Cap in billion HKD as of 30/12/2004
Beijing Yanhua Petrochemical Co. Ltd	325	BYH	Basic materials	Chemicals – plastics and rubber	1997-6-25	1997-6-24	1997-6-25	1:8	1.55	3.80
China Eastern Airlines Co. Ltd.	670	CEA	Transportation	Airline	1997-2-5	1997-2-5	1997-2-5	1:100	1.27	2.68
China Southern Airlines Company Ltd.	1055	ZNH	Transportation	Airline	1997-7-31	1998-4-16	1998-4-16	1:50	3.82	3.70
China Mobile (Hong Kong) Ltd.	941	CHL	Service	Communications services	1997-10-23	1997-10-22	1997-10-23	1:5	13.88	497.69
Guangshen Railway Company Limited	525	GSH	Transportation	Railroads	1996-5-14	1996-5-13	1996-5-14	1:50	3.57	4.26
Huaneng Power International, Inc.	902	HNP	Utilities	Electric utilities	1998-1-22	1994-10-6	1998-1-22	1:40	4.83	8.78
Sinopec Shanghai Petrochemical Co. Ltd	338	SHI	Energy	Oil and gas operations	1993-7-26	1993-7-26	1993-7-26	1:100	1.33	6.58
Yanzhou Coal Mining Company Limited	1171	YZC	Mining	Mines	1998-4-1	1998-4-1	1998-4-1	1:50	1.80	11.83

discovery in terms of the variance of innovations to the common factor. Thus, the IS model measures each market's relative contribution to this variance. This contribution is named market's information share.

3.2.1. Permanent–transient model

Consider two cointegrated I(1) price series, $P_t=(P_{1t},P_{2t})'$. A vector error–correction (VECM) model can be estimated as follows:

$$\Delta P_t = \alpha \cdot \beta' P_{t-1} + \sum_{j=1}^{k} A_j \Delta P_{t-j} + e_t, \tag{1}$$

where α is the error–correction vector, β is the cointegrating vector and e_t is a zero–mean vector of serially uncorrelated innovations with covariance matrix Ω such that:

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}. \tag{1a}$$

σ_1^2 (σ_2^2) is the variance of e_{1t} (e_{2t}) and ρ is the correlation between e_{1t} and e_{2t}. Note that $\alpha \cdot \beta' P_{t-1}$ represents the long-run equilibrium dynamics between the price series, and $\sum_{j=1}^{k} A_j \Delta P_{t-j}$ depicts the short-run dynamics induced by market imperfections.

The specification is analogous to Stock and Watson's (1988) common trend representation:

$$Y_t = f_t + G_t, \tag{2}$$

where f_t is the common factor component and G_t is the transitory component that does not have a permanent impact on Y_t. Gonzalo and Granger (1995) define the common factor to be a combination of the variables $Y_t=(y_{1t},y_{2t})$, such that $f_t=\Gamma Y_t$, where $\Gamma=(\gamma_1,\gamma_2)$ is a 1×2 common factor coefficient vector. They show that Γ is orthogonal to the error–correction coefficient vector α, denoted by $\Gamma=\alpha_\perp'$. Γ is normalized so that $\sum \gamma_i=1$. The specification f_t can be considered as a portfolio of prices from each market with Γ serving as the portfolio weights (Harris et al., 2002). Therefore, the contribution of the first (second) market to the price discovery can be measured by γ_1 (γ_2).

3.2.2. Information share model

Hasbrouck (1995) transformed Eq. (1) into a vector moving average (VMA) process:

$$\Delta P_t = \psi(L) e_t, \tag{3}$$

its integrated form is:

$$P_t = \iota\psi\left(\sum_{s=1}^{t} e_s\right) + \psi^*(L) e_t, \tag{4}$$

where $\iota=(1,1)'$ is a column vector of ones, $\psi=(\psi_1,\psi_2)$ is a row vector, and $\psi^*(L)$ is a matrix of polynomials in the lag operator, L.

Eq. (4) is closely related to Eq. (2). The increment $\psi\, e_t$ from the first part of Eq. (4) is the component of price change that is permanently impounded into the price. If one decomposes the variance of the common factor innovations, $\text{var}(\psi e_t)=\psi\Omega\psi'$, the information share of a market is the proportion of var(ψe_t) that is attributable to innovations in that market. If covariance matrix Ω is diagonal, the information share of the j-th market is given by:

$$S_j = \frac{\psi_j^2 \sigma_j^2}{\psi \Omega \psi'}, \tag{5}$$

where ψ_j is the j-th element of ψ. If Ω is not diagonal, the information share cannot be obtained analytically.

Baillie et al. (2002) examine the relationship between the PT and IS model and prove that $\frac{\psi_1}{\psi_2} = \frac{\gamma_1}{\gamma_2}$. Therefore, if there is no correlation between the error terms, the information share can be computed directly from

$$S_j = \frac{\gamma_j^2 \sigma_j^2}{\gamma_1^2 \sigma_1^2 + \gamma_2^2 \sigma_2^2} \tag{6}$$

and

$$\frac{S_1}{S_2} = \frac{\gamma_1^2 \sigma_1^2}{\gamma_2^2 \sigma_2^2}. \tag{7}$$

However, if the price innovations are significantly correlated across markets, Eq. (6) does not hold. One can use the Cholesky factorization of $\Omega = MM'$ to eliminate the contemporaneous correlation, where

$$M = \begin{pmatrix} m_{11} & 0 \\ m_{12} & m_{22} \end{pmatrix} = \begin{pmatrix} \sigma_1 & 0 \\ \rho\sigma_2 & \sigma_2(1-\rho^2)^{1/2} \end{pmatrix} \tag{8}$$

is a lower triangular matrix. The information share is given by:

$$S_j = \frac{([\psi M]_j)^2}{\psi \Omega \psi'}, \tag{9}$$

where $[\psi M]_j$ is the j-th element of the row of matrix ψM.

Baillie et al. (2002) derive that,

$$\frac{S_1}{S_2} = \frac{(\gamma_1 m_{11} + \gamma_2 m_{12})^2}{(\gamma_2 m_{22})^2}. \tag{10}$$

Since $S_1 + S_2 = 1$,

$$S_1 = \frac{(\gamma_1 m_{11} + \gamma_2 m_{12})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2}, \tag{11}$$

and

$$S_2 = \frac{(\gamma_2 m_{22})^2}{(\gamma_1 m_{11} + \gamma_2 m_{12})^2 + (\gamma_2 m_{22})^2}. \tag{12}$$

Eqs. (11) and (12) show that information share depends on $\Gamma = (\gamma_1, \gamma_2)$ and Ω. The factorization imposes a greater information share on the first price, unless there is no correlation between market innovations (i.e., $m_{12} = 0$). Hasbrouck (1995) considers the upper (lower) bound of market j's information share when market j is the first (second) variable in the factorization. He shows that the higher the correlation, the greater (smaller) the upper (lower) bound. Using the one-second interval

Table 2
Results of the augmented Dickey–Fuller unit root test

		Lags	Eq. (13) no constant no trend	Eq. (14) constant but no trend	Eq. (15) constant and trend
BYH	HK	0	−0.2506	−1.4339	−1.9239
	NY	1	−0.3978	−1.6180	−2.0656
CEA	HK	0	−0.6843	−2.2945	−2.2797
	NY	0	−0.5874	−2.0477	−2.0208
CHL	HK	2	−0.5622	−1.6959	−1.6592
	NY	0	−0.6313	−1.8373	−1.7751
GSH	HK	2	−0.8565	−1.6451	−1.2262
	NY	0	−0.8755	−1.6462	−1.1806
HNP	HK	2	0.8493	−0.1531	−2.5062
	NY	0	0.8138	−0.2175	−2.4640
SHI	HK	0	−0.5168	−2.1312	−2.0433
	NY	0	−0.4175	−1.9602	−1.8518
YZC	HK	2	2.2374	1.4848	−0.6013
	NY	2	2.3086	1.5704	−0.5029
ZNH	HK	0	−1.5151	−3.0336	−4.8472***
	NY	0	−1.4879	−2.9675	−4.6756***

Note:
The number of lags is determined by Schwartz Bayesian Criterion.
The critical value at the 1% significance level is −2.58 for Eq. (13).
The critical value at the 1% significance level is −3.43 for Eq. (14).
The critical value at the 1% significance level is −3.96 for Eq. (15).
*** Significant at the 1% level.

of prevailing quotes, Hasbrouck (1995) reports that the upper bounds and the lower bounds are almost the same. Baillie et al. (2002) show that the average of the lower and upper bounds is a reasonable estimate of a market's contribution to price discovery.

In our study, we will follow the methodology of Baillie et al. (2002) in computing the information share of Hasbrouck's (1995) model. After obtaining the error–correction coefficient vector of $\alpha=(\alpha_1,\alpha_2)$, and its orthogonal vector $\Gamma=(\gamma_1, \gamma_2)$, the covariance matrix of the error terms will be computed. If the correlation coefficient of the error terms is significantly different from zero, Cholesky factorization of Ω will be employed to obtain the information share in Eqs. (11) and (12). Since this method imposes a greater information share on the first price, both upper bound and lower bound of each price will be calculated and the average of these two bounds will be reported as the information share.

3.3. Empirical results

In our study, we examine the pair $(P_t^{\mathrm{HK}}, P_{t-1}^{\mathrm{NY}})$, where P_t^{HK} is the closing price of the SEHK at time t, and P_{t-1}^{NY} is the closing price of the NYSE at time $t-1$.

We first check whether the two price series for each stock are I(1) processes. The Augmented Dickey and Fuller (1981) test is performed to test for the presence of a unit root. For each price series, we estimate the following three regression equations.

$$\Delta P_t = \gamma P_{t-1} + \sum_{i=1}^{p} \phi_i \Delta P_{t-i} + e_t, \tag{13}$$

$$\Delta P_t = c_0 + \gamma P_{t-1} + \sum_{i=1}^{p} \phi_i \Delta P_{t-i} + e_t, \tag{14}$$

$$\Delta P_t = c_0 + \gamma P_{t-1} + c_1 t + \sum_{i=1}^{p} \phi_i \Delta P_{t-i} + e_t. \tag{15}$$

The null hypothesis is that $\gamma = 0$. If the null hypothesis cannot be rejected, the P_t series contains a unit root. Schwarz Bayesian Criterion (SBC) will be used to determine the optimal number of lags in the model. The results of Augmented Dickey–Fuller unit root test are reported in Table 2.

In general, we conclude that both price series for each stock are I(1) processes.

We now check whether (P_t^{HK},P_{t-1}^{NY}) are cointegrated of order 1. We estimate the long-run equilibrium relationship between the two variables by the following equation:

$$P_t^{\mathrm{HK}} = \beta_0 + \beta_1 P_{t-1}^{\mathrm{NY}} + e_t. \tag{16}$$

Denote the residual sequence from above by $\{\hat{e}_t\}$. If the estimated residual series $\{\hat{e}_t\}$ is found to be stationary, then the two series are cointegrated. To check whether the residual series is a stationary process, a unit root test is performed on the estimated residual series:

$$\Delta \hat{e}_t = a_1 \hat{e}_{t-1} + \varepsilon_t. \tag{17}$$

The Engle–Granger test results are reported in Table 3.

For all eight companies, the estimated coefficients of β_1 for the price series (P_t^{HK},P_{t-1}^{NY}) are significant at the 1% level. The magnitude of β_1 is within the range of (0.990, 1.005). We test the

Table 3
Engle–Granger cointegration test

Company	β_1 (*t*-stat.)	a_1 (*t*-stat.)
CEA	0.992	−0.651
	(360.175)***	(−31.442)***
ZNH	1.000	−0.694
	(392.925)***	(−31.826)***
CHL	0.994	−0.887
	(598.842)***	(−35.263)***
GSH	0.990	−0.612
	(583.845)***	(−30.043)***
HNP	1.000	(−0.773)
	(920.070)***	(−33.514)***
SHI	1.001	−0.696
	(419.981)***	(−33.056)***
YZC	1.000	−0.715
	(633.595)***	(−31.063)***
BYH	0.994	−0.574
	(389.331)***	(−28.060)***

Note:
β_1 is estimated coefficient from regression Eq. (16).
a_1 is estimated coefficient of Dickey–Fuller test of estimated residuals: $\Delta\hat{e}_t = a_1\hat{e}_{t-1} + \varepsilon_t$.
The critical value for a_1 at the 1% and 5% level are −3.92 and −3.35.
*** Significant at the 1% level.

null hypothesis, H_0: $\beta_1 = 1$, for each pair of price series. The null cannot be rejected at the 5% level for both pairs of prices. This suggests that there is no persistent price difference between the share prices listed on the SEHK and the NYSE for these eight stocks. The estimated coefficients of a_1 are all statistically significant. Therefore, the null hypothesis that $a_1 = 0$ is rejected, which implies that the estimated residual series are stationary. From Table 3, we conclude that the price series for all companies are cointegrated at the 1% significance level. Thus, an error–correction model can be estimated. As the residual $\hat{e}_t$ estimates the deviation from the long-run equilibrium in period t, we are able to run the following error–correction regressions:

$$\Delta P_t^{\mathrm{HK}} = \alpha_0^{\mathrm{HK}} + \alpha_1^{\mathrm{HK}} \hat{e}_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta P_{t-i}^{\mathrm{HK}} + \sum_{i=1}^{p} \delta_i \Delta P_{t-i}^{\mathrm{NY}} + \varepsilon_t^{\mathrm{HK}}, \tag{18}$$

$$\Delta P_t^{\mathrm{NY}} = \alpha_0^{\mathrm{NY}} + \alpha_1^{\mathrm{NY}} \hat{e}_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta P_{t-i}^{\mathrm{HK}} + \sum_{i=1}^{p} \delta_i \Delta P_{t-i}^{\mathrm{NY}} + \varepsilon_t^{\mathrm{NY}}. \tag{19}$$

The estimated error–correction coefficients (α_1^{HK},α_1^{NY}) are the main focus of our research. We report the error–correction coefficient that is significant at the 5% level. For those that are not significant, they will be substituted with zero. The estimated error–correction coefficients are reported in Table 4.

We also report the price-discovery contribution for (P_t^{HK},P_{t-1}^{NY}) in Table 5. For the eight cross-listed stocks, the SEHK contributes substantially to the price-discovery process.

Table 4
Engle–Granger error–correction coefficient: obtained by using SEHK(t) and NYSE(t) and SEHK(t) and NYSE($t-1$) closing prices

Firm	(P_t^{HK},P_{t-1}^{NY})	
	α_1^{HK}	α_1^{NY}
CEA	−0.077	0.322
ZNH	−0.077	0.414
CHL	−0.247	0.583
GSH	0	0.330
HNP	−0.122	0.351
SHI	−0.105	0.381
YZC	0	0.327
BYH	−0.108	0.203
Mean	−0.094	0.364
Median	−0.105	0.351
SD	0.073	0.101

Note:
The α_1^{HK} and α_1^{NY} are estimated from the following error–correction models:

$$\Delta P_t^{\mathrm{HK}} = \alpha_0^{\mathrm{HK}} + \alpha_1^{\mathrm{HK}} \hat{e}_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta P_{t-i}^{\mathrm{HK}} + \sum_{i=1}^{p} \delta_i \Delta P_{t-i}^{\mathrm{NY}} + \varepsilon_t^{\mathrm{HK}}$$

$$\Delta P_t^{\mathrm{NY}} = \alpha_0^{\mathrm{NY}} + \alpha_1^{\mathrm{NY}} \hat{e}_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta P_{t-i}^{\mathrm{HK}} + \sum_{i=1}^{p} \delta_i \Delta P_{t-i}^{\mathrm{NY}} + \varepsilon_t^{\mathrm{NY}}$$

If the coefficient is not significant, we substitute it with zero.

Table 5
Gonzalo–Granger common factor coefficients and Hasbrouck information shares: obtained from SEHK(t) closing and NYSE($t-1$) closing price

Firm	Cross-market correlation coefficients[a]	Common factor coefficients[b]		Information shares[c]	
		P_t^{HK}	$P_{t\text{-}1}^{NY}$	P_t^{HK}	$P_{t\text{-}1}^{NY}$
CEA	0.110	0.807	0.193	0.969	0.031
ZNH	0.194	0.843	0.157	0.953	0.047
CHL	0.529	0.702	0.298	0.729	0.271
GSH	0.239	1.000	0.000	0.972	0.028
HNP	0.375	0.742	0.258	0.843	0.157
SHI	0.209	0.784	0.216	0.932	0.068
YZC	0.113	1.000	0.000	0.994	0.006
BYH	0.373	0.653	0.347	0.757	0.243
Mean	0.268	0.816	0.184	0.894	0.106
SD	0.146	0.128	0.128	0.104	0.104
Median	0.224	0.796	0.205	0.943	0.058

Note:
[a] Coefficients of correlation between the residuals from the VECM.
[b] The common factor coefficient vector is estimated according to Gonzalo and Granger (1995).
[c] The information shares are estimated using the Hasbrouck (1995) model. Reported shares are the averages of the lower and upper bounds of the information shares.

Since China Mobile and Sinopec Beijing Yanhua do not issue shares in the Chinese stock market, we exclude them and re-examine each market's contribution. The contributions of the SEHK and the NYSE become (0.863, 0.137) and (0.944 0.056) now for PT model and IS model respectively. Therefore, for the six stocks that have issued shares in China, the SEHK plays a more significant role in finding their implicit efficient prices. An explanation for this finding is that both measures of price discovery are an explicable function of trading volume because informed traders seek to stealth trade against more numerous counterparties with larger order flows, thus, the NYSE results, as small as they are, become even smaller when the Chinese stock also trades on the Shanghai or Shenzhen exchanges. In a nutshell, the results suggest that for cross-listed China-backed stocks, the SEHK contributes more to the price-discovery process.

4. Conclusion

International cross-listing has become increasingly common in recent years. A number of firms have cross-listed their shares on foreign exchanges. This has raised several interesting questions, such as the motivation and rationale of international cross-listing, and the effect of the cross-listing on the domestic stock performance. Since the early 1990s, Chinese state-owned enterprises have begun to list their securities overseas. The overseas listings have been improving the corporate governance of large SOEs and enhancing their international image. The two major markets where the Chinese enterprises list their stocks on are the SEHK and the NYSE. Thus, it would be interesting to study the relative importance of the two markets to the stock prices of these Chinese companies. In this study, we have examined price-discovery contributions of the two exchanges to a number of cross-listed Chinese stocks. Analyzing the daily closing price of eight China-backed stocks cross-listed on the NYSE and the SEHK, we find that the prices of the same stock in the SEHK and the NYSE are cointegrated with one common factor. We calculate the price-discovery contribution of the NYSE and the SEHK using the Gonzalo and Granger (1995) PT model and Hasbrouck (1995) IS model. It is shown that the SEHK contributes more to the price-discovery process of the eight stocks.

There are two possible explanations for our findings: First, due to the close economic relationship, linguistic and geographical proximity between China and Hong Kong, Hong Kong may be regarded as a domestic market of China (Xu and Fung, 2002). If we consider the Hong Kong market to be a domestic market compared with the NYSE, our conclusion will be in line with Lieberman et al. (1999). In their study, they also use daily closing prices and find that Israeli market has stronger influence on share prices in the U.S.. Second, Hong Kong and China are in the same time zone. Since important information is likely to be released during the home-market business hours, the closing price of the HK market should incorporate more valuable information than the closing price of the U.S. market.

Finally, we also find that the NYSE's contribution is smaller if the stock is also listed on the China stock exchanges. It should be mentioned that our paper deals with the interrelations between stocks listed and traded in two international unsynchronized markets. Thus, our results should be interpreted with caution because of the potentially debilitating nature of using non-synchronous closing prices. Since the Hong Kong market closes 12 h after the close of NYSE on the previous day, the Hong Kong closing price is likely to incorporate more information than the New York closing price, resulting in a higher information share of the SEHK. An appropriate direction for future research is to see how our findings with non-synchronous data will be affected when we estimate the models with after-hours trading of the Chinese ADRs in New York or with the overlapping trading between Hong Kong and Tokyo.

References

Baillie, R.T., Booth, G.G., Tse, Y., Zabotina, T., 2002. Price discovery and common factor models. Journal of Financial Markets 5, 309–321.

Dickey, D.A., Fuller, W.A., 1981. Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49, 1057–1072.

Ding, D.K., Harris, F.H.deB., Lau, S.T., McInish, T.H., 1999. An investigation of price discovery in informationally-linked markets: equity trading in Malaysia and Singapore. Journal of Multinational Financial Management 9, 317–329.

Eun, C.S., Sabherwal, S., 2003. Cross-border listings and price discovery: evidence from U.S.-listed Canadian stocks. Journal of Finance 58, 549–574.

Garbade, K.D., Silber, W.L., 1979. Dominant and satellite markets: a study of dually-traded securities. Review of Economics and Statistics 61, 455–460.

Gonzalo, J., Granger, C., 1995. Estimation of common long-memory components in cointegrated systems. Journal of Business and Economic Statistics 13, 27–35.

Grammig, J., Melvin, M., Schlag, C., 2005. Internationally cross-listed stock prices during overlapping trading hours: price discovery and exchange rate effects. Journal of Empirical Finance 12, 139–164.

Harris, F.H.deB., McInish, T.H., Shoesmith, G.L., Wood, R.A., 1995. Cointegration, error correction, and price discovery on informationally linked security markets. Journal of Financial and Quantitative Analysis 30, 563–579.

Harris, F.H. deB., McInish, T.H., Wood, R.A., 2002. Security price adjustment across exchanges: an investigation of common factor components for Dow stocks. Journal of Financial Markets 5, 277–308.

Hasbrouck, J., 1995. One security, many markets: determining the contributions to price discovery. Journal of Finance 50, 1175–1199.

Kadapakkam, P., Misra, L., Tse, Y., 2003. International price discovery for emerging market stocks: evidence from Indian GDRs. Review of Quantitative Finance and Accounting 21, 179–199.

Lieberman, O., Ben-Zion, U., Hauser, S., 1999. A characterization of the price behavior of international dual stocks: an error correction approach. Journal of International Money and Finance 18, 289–304.

Pascual, R., Pascual-Fuster, B., Climent, F., 2001. Cross-listing, price discovery and the informativeness of the trading process. Working Paper. Universidad de las Islas Beleares.

Schreiber, P.S., Schwartz, R.A., 1986. Price discovery in securities markets. Journal of Portfolio Management 12, 43–48.

So, R., Tse, Y., 2004. Price discovery in the Hang Seng Index markets: index, futures, and the Tracker fund. Journal of Futures Markets 24, 887–907.

Stock, J.H., Watson, M.W., 1988. Testing for common trends. Journal of American Statistical Association 83, 1097–1107.

Wang, S.S., Jiang, L., 2004. Location of trade, ownership restrictions, and market illiquidity: examining Chinese A- and H-shares. Journal of Banking and Finance 28, 1273–1297.

Xu, X.E., Fung, H.G., 2002. Information flows across markets: evidence from China-backed stocks dual-listed in Hong Kong and New York. The Financial Review 37, 563–588.