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Where does price discovery occur for stocks traded in multiple markets? Evidence from Hong Kong and London

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Abstract

Using a sample of Hong Kong-listed stocks that are also traded on the London Stock Exchange, we document the following results: first, London market makers use Hong Kong's closing prices as the benchmark for setting the opening prices in London. Second, trading in the London market plays only a limited role in price discovery in the Hong Kong market. Third, the stock returns from London trading are closely correlated with those of the Hong Kong market. The above findings are consistent with the explanation that London trading is predominantly liquidity-driven but not information-driven.

JEL classification: G14; G15

Keywords: Dually listed stocks; Price discovery; Liquidity-driven trading

1. Introduction

International capital markets are becoming increasingly integrated due to advances in information technology which has resulted in significantly lower costs for cross-border financial transactions. Furthermore, a worldwide trend towards international capital market liberalization

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has reduced regulatory barriers and enhanced information flows among stock markets allowing for a dramatic increase in cross-border listings and trading over the last decade.

Although the increase in international trading has received a great deal of attention in academic literature, financial economists have been unable to provide a straightforward answer to the simple question, ''where does the price discovery process occur for internationally traded stocks?'' Our inability to answer this question may be attributed to the mixed empirical evidence compiled by previous studies. While it seems sensible to assume that home market trading dominates the price discovery process, a number of confounding factors prevent us from positively confirming this. The question of where price discovery occurs for stocks traded in multiple markets is the main focus of this study.

Based on the analysis of high-frequency data from three large German blue-chip stocks traded in New York and Frankfurt, Grammig et al. (in press) report that price discovery occurs largely in the home market (Frankfurt) with significant information sharing between the Frankfurt and New York markets. Grammig et al. (2004) draw similar conclusions: they report that most of foreign stocks traded simultaneously in New York and their home markets have the largest fraction of price discovery occurring at the home markets with the New York market taking a smaller role. Kim et al. (2000) find that home market prices in the local currencies of American Depositary Receipts (ADRs) are the most important factor in ADR prices in the U.S. market. Nevertheless, they also observe that both exchange rates and U.S. market movements have an impact on ADR prices. Eun and Sabherwal (2003) examine the extent to which U.S. trading contributes to price discovery in Canadian stocks cross-listed in the United States. They find that price adjustments occur in both Toronto and New York, with New York prices adjusting more to Toronto prices than vice versa. An earlier study by Neumark et al. (1991) reports that after-hours trading in international markets of multiply-listed Dow Jones Industrial Average component stocks, predicted New York prices in the weeks immediately following the October 1987 market crash. However, they did not predict New York prices in the succeeding months. Neumark et al. also show the importance of home market price discovery with their finding that daily New York price changes incorporate after-hour trading on the international markets.

In contrast, Werner and Kleidon (1996) report that New York intraday trading patterns of British cross-listed stocks are virtually unaffected by London market trading which is conducted for 6 h prior to the New York open. They also find that the London intraday trading pattern is affected only to a very limited degree by New York trading. Their findings indicate that each market's trading leaves its own distinct ''footprints.'' Bodurtha et al. (1995) find that the prices of closed-end country funds are influenced by U.S. market movements although their net asset values are not. Another related but similar finding is compiled by Froot and Dabora (1999). They report that the relative prices of twin stocks are highly correlated with the relative stock-market indexes of the countries where the twin stocks are traded most actively. Chan et al. (2003) observe that after being delisted from the Hong Kong market, the co-movement of Jardine stock returns with the Hong Kong market declined but that the co-movement with the Singapore market increased even though the majority of Jardine's business remained in Hong Kong.

From the above discussion, the impact of private information generated during trading hours appears to be the main source of the interaction between the two markets. Werner and Kleidon (1996), for example, observe higher volatility and trading volume for British cross-listed stocks than non-cross-listed stocks during the 2-h overlapping trading period. They attribute these findings to private information originating in New York that is incorporated into the prices

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of both markets. Since Toronto and New York trading hours overlap, it is not surprising that Eun and Sabherwal (2003) observe cross-market information flows taking place not only on the U.S. exchanges but also in the Toronto Stock Exchange for Canadian cross-listed stocks. They report that the U.S. contribution to price discovery in Toronto is a positive function of the higher U.S. share of total trading and the proportion of medium-sized trades but a negative function of the bid and ask spreads in the U.S. market. Again, their findings point to the impact of information flow. Ding et al. (1999) observe that approximately 70% of the price discovery occurs in the Kuala Lumpur market which is the home country of a sample stock, while the remainder of the price discovery is attributable to the Singapore market trading. Again, both markets are open and close simultaneously and may be considered informationally-linked.[1] Bacidore and Sofianos (2002) find that higher levels of information asymmetry and increased adverse selection risks are the major reasons for the differences in market quality of U.S. and non-U.S. stocks traded on the New York Stock Exchange as reflected in the specialist trading behavior. The integration of the home and the international markets during the October 1987 market crash, as documented by Neumark et al. (1991), also points to the influence of a common information shock. Chan et al. (1996) rely on public information to explain the differential intraday volatility behaviors of European and Japanese dually listed stocks in New York and comparable U.S. stocks.

Evidence shows that public and private information is the underlying reason why separate markets appear integrated, which in turn makes it difficult to determine the answer to the question "where does the price discovery occur for internationally traded stocks." In addressing this question, this study provides new insights, as well as empirical evidence, that without information revelation, the international trading of cross-listed stocks plays an insignificant role in the price discovery process. Our main hypothesis is simple: if the international trading of stocks listed in multiple markets is liquidity- rather than information-driven, international market prices fully incorporate home market prices but not vice versa. A subset of Hong Kong Exchange (HKEx)-listed stocks that are also traded in London is an ideal candidate to test this hypothesis.[2]

From an empirical perspective, choosing to follow trading in London and Hong Kong gives us a few additional advantages.[3] First, both Hong Kong and London are vibrant financial centers with easy access for international and domestic investors. Second, the London market is the major alternative trading venue for Hong Kong-listed stocks for European and U.S. investors. Most important of all, London trading of Hong Kong-listed stocks is dominated by institutional investors, especially European and U.S. international funds. In a survey conducted by the Hong Kong Securities and Futures Commission, London market makers indicate that a very large

[1] Baruch et al. (2003) provide both theoretical and empirical explanations for the distribution of trading volume across exchanges competing for order flow. They predict that the correlation of the cross-listed asset returns with the returns of other assets traded in the respective markets is the critical variable in explaining the trading volume in competing markets.

[2] Prior to the incorporation of the Hong Kong Exchanges and Clearing Limited (HKEx) in March 2000, the Stock Exchange of Hong Kong was known as SEHK. We are using the acronym HKEx throughout this paper for consistency with the Exchange's current practice even though trading occurred during the period, January–March 1996, while the exchange was still known as the SEHK.

[3] We also considered investigating New York trading of Hong Kong-listed stocks but most of the New York trades are retail transactions on the over-the-counter (OTC) "pink-sheet" market. Moreover, the OTC daily volume of Hong Kong stocks (in terms of both the number of shares traded and the dollar value of the shares traded) is usually low.

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proportion of trades are conducted for portfolio rebalancing purposes incorporating program trading and index fund trading. This suggests that these trades are more liquidity- than information-driven.[4] Third, both Hong Kong and London markets trade these stocks in Hong Kong dollars. Therefore, we avoid the foreign exchange-related confounding effects that exist in most of the previous studies on multi-market trading as identified by Werner and Kleidon (1996) and Grammig et al. (in press). According to Werner and Kleidon, studies examining stocks that are traded in different forms of claims and currency denominations, in different markets, suffer from at least two problems: (i) the two securities are not necessarily perfect substitutes for all investors; (ii) the intraday exchange rate volatility can induce a new risk factor in pricing these international securities. Fourth, there is no overlap of the trading hours of the London and Hong Kong markets.

This study is not the first one to choose the dually listed stocks in Hong Kong and London as the subject matter for examining the transmission of pricing information between two markets. Bae et al. (1999) show that the transmission of information runs into both directions, though the impact is much stronger moving from the LSE to the HKEx. It is worth noting that their methodology was only designed to capture the transfer of systematic information between Hong Kong and London. According to O'Hara (1995), the information from multi-market trading activity can be divided into two separate components: systematic and non-systematic information. The non-systematic information pertains to only a single security, whereas the systematic information pertains to all securities, i.e. the market. Usually, the developed markets such as the U.S. and the London markets reveal systematic information. This is demonstrated by evidence indicating that the movement of the U.S. market affects other markets, but not vice versa. Hence, by focusing on the transmission of the systematic information, it is not surprising that Bae et al. (1999) find that the London market has a much stronger impact on Hong Kong stock trading than the Hong Kong market has on London stock trading. Recently, Wang et al. (2002) examine the spillovers between the Hong Kong market and the London market using GJR−GARCH (1, 1) models. They provide evidence of returns and volatility spillovers from Hong Kong to London, as well as from London to Hong Kong.

Given the conflicting findings compiled by Bae et al. (1999) and Wang et al. (2002), the question of where the price discovery occurs has yet to be resolved. Especially, the role of the London market in price discovery warrants further analyses. In addition, these papers use opening and closing prices to calculate stock returns over different intervals, e.g., the intraday return and the overnight return. This does not cause serious concern for the examination of Hong Kong trading since these stocks are actively traded on HKEx. However, the London trading process for those stocks is characterized by a large number of shares per trade but fewer transactions. The stale opening and closing prices may present a serious problem in computing the intraday returns and overnight returns of London trading.[5] To avoid this issue, we use ask and bid prices at the opening and closing of the market to measure the returns from London trading even though bid and ask prices are not transaction prices, we believe that these prices impound the necessary information available at the time they are quoted.

To the best of our knowledge, this analysis is the first empirical effort to investigate the question of where the price discovery occurs for cross-listed stocks when the international trading is

[4] See Chang et al. (1997).

[5] Bae et al. (1999) point out that the use of stale opening prices in computing intraday returns may result in some of the puzzling findings of their study.

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predominantly liquidity-driven.[6] One advantage of our study is a parsimonious framework of return-based analyses. Without relying on complex time-series models that capture both returns and volatility, we are able to demonstrate that the home market is the primary location for price discovery using our return-based analyses.

The important findings of this study include the following: first, we investigate the dynamics of the price transmission processes between the Hong Kong closing and London opening prices as well as between the London closing and Hong Kong opening prices. Our evidence indicates that the closing prices in the Hong Kong market are fully incorporated into London's opening prices. However, the reverse is not true. Second, trading in London has little explanatory power in predicting overnight changes in prices in the Hong Kong market, confirming that trading in the London market plays an insignificant role in the price discovery process of the Hong Kong market. Conversely, the overnight returns of the London market can be largely explained by trading in Hong Kong. Third, the results from regression analyses demonstrate that stock returns from London trading are closely correlated with Hong Kong market movements but not with the London market movements. The above findings are not interpreted as evidence that pricing inefficiency exists between the London and Hong Kong trading. Rather, they are consistent with the explanation that London trading is not information-driven but predominately driven by liquidity traders. Hence, London market makers utilize the price discovery from the Hong Kong market to satisfy the liquidity demands of European and U.S. institutional investors.

The rest of the paper is organized as follows. In Section 2, we provide a brief description of the institutional backgrounds of the London and Hong Kong markets, the data, and sample statistics. In Section 3 we analyze price discovery between the Hong Kong and London markets. In Section 4 we provide closing comments and a summary.

2. Institutional background and the data

2.1. London trading of Hong Kong-listed stocks

Although the London market for foreign securities has existed for a long time, the trading of such securities had been largely conducted outside of the formal market. The formation of the International Stock Exchange provided an opportunity to formalize and enlarge this market. The International Stock Exchange operated in the European time zone, between the New York and Tokyo markets. The screen-based Stock Exchange Automated Quotations (SEAQ) International system, created in June 1985, provides the price dissemination facility of over 600 overseas securities. Like the U.K. domestic equity market, the SEAQ International equity market uses a market maker system, with 50 market makers quoting continuous two-way prices. In this system, market makers key their bid and ask prices directly into a central computer system and investors contact the market makers by telephone when executing a trade. As for settlement and transfer, once the investor and market maker execute their trade, they decide when settlement will occur. The average transaction value on the SEAQ International, over $350,000 during our study period in 1996, reflects the dominance of institutional investors. Hong Kong-listed stocks are quoted in Hong Kong dollars

[6] In the theoretical models of Chowdhry and Nanda (1991) and Grossman (1992), price discovery is examined when traders have access to multiple trading venues. However, in their framework, stocks are traded on multiple markets simultaneously. Therefore, the case of London trading of HK-listed stocks may not be consistent with the underlying assumption of their models.

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in London because share prices are usually quoted in the home currency of each security and transactions are settled through the local settlement system. Trading in the London international equity market may go on 24 h a day but quotations must be keyed into the SEAQ International computer system between 7:00 AM and 20:00 PM, GST.

The HKEx is a purely order-driven market. Share prices are determined by the buy and sell orders submitted by investors in the absence of designated market makers. Limit orders are placed through brokers and are consolidated in an electronic limit-order book and executed through an automated trading system known as the Automatic Order Matching and Execution System.

2.2. Data description

Our sample consists of 17 stocks that are traded in both Hong Kong and London. Specifically, we select the sample stocks based on two criteria: (i) stocks that had London trading volume equal to or greater than 10% of their volume on the HKEx; and (ii) stocks that had price quotations by London market makers on the SEAQ International.[7] Two data sources are used to gather the data. The London trading information for 17 selected stocks was obtained from the LSE, including both trade and quote data for individual stocks on SEAQ International. The sources of the Hong Kong data are the HKEx, the Hong Kong Securities and Futures Commission, and the PACAP-Hong Kong databases. The data include opening prices, closing bid and ask prices, as well as number of trades and trading volume.[8] The study period covers the three months between January 1996 and March 1996.

In Table 1, we present the distribution of LSE trades by the London hour of the day. Since the London market opens 1.5 h after the Hong Kong market's closing bell, we observe a sudden jump in trading activity at that time.[9] Approximately 35% of all trades are conducted within the first 3 h following the opening bell and over 30% of the trades are conducted in the 3 h prior to the closing bell. Furthermore, the results show some trading activities while the London market is closed. This is possible because London trading data do not distinguish between on and off market transactions. Irrespective of where London market makers actually transact they must report the trade to the LSE and we suspect that some of these trades represent Hong Kong trading but are executed by London-based market makers.[10]

In Table 2, we present the trading activities in London and Hong Kong for each stock in the sample on a monthly basis. There is some interesting information contained in these trading activities. The average trading volume in London, as a proportion of the Hong Kong volume, ranges from 37% to 40% over the three-month period. However, wide variations are observed among the 17 securities. HSBC Holdings has an average trading volume in London, as a proportion of Hong Kong, of over 68% while Hang Lung Development Company has an average of 13% over the three-month period. Hong Kong Telecom is the most actively traded stock on both

[7] In addition, the firms that have been delisted from the HKEx (the notable example is Jardin Group companies) are excluded.

[8] Only the closing bids and asks' prices from Hong Kong were made available by the Hong Kong Securities and Futures Commission. The PACAP-Hong Kong databases report only daily closing, high and low prices. The opening prices of the sample stocks have been manually collected from hard copies of trading sheets provided by HKEx.

[9] Morning and afternoon trading hours in Hong Kong are 2:00 AM–4:30 AM, G.M.T. and 6:30 AM–8:00 AM, respectively, and London trading begins at 9:30 AM and ends at 3:30 PM during the study period.

[10] The distribution of reported trades over time provides a good indication of where these reported London trades actually took place. Chang et al. (1997) estimate that approximately 14% of London trades are in fact Hong Kong trading by London market makers since these trades are reported during Hong Kong trading hours.

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Table 1
Distribution of London trading by the hour of the day

		London time		Proportion of LSE volume (%)
		From	To	
		1:00 AM	2:00 AM	0.02
HK open	---------->	2:00 AM	3:00 AM	0.03
		3:00 AM	4:00 AM	0.04
		4:00 AM	5:00 AM	0.09
		5:00 AM	6:00 AM	0.15
		6:00 AM	7:00 AM	0.58
		7:00 AM	8:00 AM	0.85
HK close	---------->	8:00 AM	9:00 AM	10.91
London open	---------->	9:00 AM	10:00 AM	12.46
		10:00 AM	11:00 AM	11.44
		11:00 AM	12:00 PM	7.78
		12:00 PM	1:00 PM	10.32
		1:00 PM	2:00 PM	4.68
		2:00 PM	3:00 PM	4.00
London close	---------->	3:00 PM	4:00 PM	10.32
		4:00 PM	5:00 PM	13.40
		5:00 PM	6:00 PM	6.40
		6:00 PM	7:00 PM	3.08
		7:00 PM	8:00 PM	2.12
		8:00 PM	9:00 PM	0.74
		9:00 PM	10:00 PM	0.51
		10:00 PM	11:00 PM	0.13
		11:00 PM	12:00 AM	0.03
		12:00 AM	1:00 AM	0.02

Notes: The table presents the distribution of LSE trades by the London hour of the day during the three-month study period from January 1996 to March 1996.

exchanges with an average monthly volume of 391 million and 173 million shares traded in Hong Kong and London, respectively.

In Table 3, we show the average trade sizes from London and Hong Kong trading. The average trade size in Hong Kong is about 8000 shares, while the figure is over 100,000 shares in London. The size of the average London trade is over 13 times greater than that of the average Hong Kong trade. Among them, HSBC, Hong Kong Telecom and Hong Kong & China Gas exhibit the largest differences between London and Hong Kong trading in terms of trade size. The large size of these London trades suggests that it is mainly the institutional investors who initiate these trades. This is confirmed by Chang et al. (1997) who report that the predominant demanders of Hong Kong securities on the London market are institutional clients of market makers and account for 98% of the volume. Chang et al. also find that a large proportion of London trading is program trading and index fund trading.

3. Price discovery in the Hong Kong and London markets

3.1. Hong Kong closing prices vs. London opening prices

We expect relative efficiency in the cross-market pricing of identical securities given that the financial markets in Hong Kong and London are both well developed. Because Hong Kong

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Table 2
Trading activity in Hong Kong and London

Company name	Hong Kong trading (thousands)			London trading (thousands)			LSE/HK (%)		
	Jan-1996	Feb-1996	Mar-1996	Jan-1996	Feb-1996	Mar-1996	Jan-1996	Feb-1996	Mar-1996
Cathay Pacific	61,982	35,160	59,312	12,188	10,557	19,148	19.66	30.02	32.28
Cheung Kong	128,654	202,200	106,197	31,548	36,117	40,379	24.52	17.86	38.02
China Light & Power	115,686	63,671	64,327	29,400	16,756	29,837	25.41	26.32	46.38
Citic Pacific	211,947	78,179	92,958	81,086	28,474	42,341	38.26	36.42	45.55
Hang Lung	106,429	39,549	31,052	15,416	5678	3518	14.48	14.36	11.33
Henderson Land	79,123	46,120	57,099	17,986	18,676	13,031	22.73	40.49	22.82
Hong Kong & China Gas	172,022	132,371	98,083	44,468	35,540	23,064	25.85	26.85	23.51
Hong Kong Telecom	598,157	332,338	243,933	126,967	204,534	188,369	21.23	61.54	77.22
Hongkong Electric	92,105	58,046	48,902	48,394	13,572	16,208	52.54	23.38	33.14
HSBC	98,685	64,554	83,889	66,962	48,733	50,091	67.85	75.49	59.71
Hutchison Whampoa	203,971	151,056	126,990	55,120	49,453	41,269	27.02	32.74	32.50
Hysan Development	52,881	28,795	45,179	20,489	12,015	15,461	38.74	41.73	34.22
New World	93,638	78,233	84,737	42,802	30,132	31,065	45.71	38.52	36.66
Sun Hung Kai	167,564	61,449	63,908	61,872	31,744	35,280	36.92	51.66	55.20
Swire Pacific	82,814	48,096	51,287	79,485	20,872	17,875	95.98	43.40	34.85
Wharf	131,874	67,050	75,057	74,055	64,171	41,954	56.16	95.71	55.90
Wheelock	66,363	27,611	31,562	6771	6008	6481	10.20	21.76	20.53
Overall average	139,353	86,142	78,545	47,942	37,237	36,198	36.66	39.90	38.81

Notes: The table presents trading activities in London and Hong Kong for each stock in the sample on a monthly basis during the three-month study period from January 1996 to March 1996. The sample consists of 17 stocks that are traded in both Hong Kong and London. The sample stocks are selected based on two criteria: (i) stocks that had London trading volume equal to or greater than 10% of their volume on the HKEx; and (ii) stocks that had price quotations by London market makers on the SEAQ International.

serves as the home market, as well as the core business location for its listed companies, it is the venue where public and private information is disclosed. London trading is predominately liquidity- rather than information-driven and, therefore, Hong Kong stocks that trade in London provide an excellent circumstance in which to examine the role of the two markets in price discovery.[11] As there is no overlapping trading period between the two markets, a natural

[11] We are grateful to the referee who kindly pointed out that the dominance of institutional trading does not necessarily mean that all trades in London are ''purely'' liquidity-driven. In our opinion, there are at least three mitigating empirical observations that support the position that London trading is largely ''liquidity-driven.'' The first piece of evidence is documented in a report prepared by Chang et al. (1997) for the Hong Kong Securities and Futures Commission. Based on field interviews with London market makers, Chang et al. report that approximately 98% of the London trading of Hong Kong-listed stocks is for portfolio rebalancing by means of program trading and index fund trading. The second piece of evidence comes from data used in this analysis. When the daytime price volatilities of the Hong Kong and London markets are compared using the stocks in our sample, we find that the price volatility in Hong Kong is three times greater than that in London. This implies that London trading is much less information-driven than Hong Kong trading. The third piece of evidence is reported by Wang et al. (2002). They report that daytime price volatility is much lower than overnight price volatility in London. This can be explained by Hong Kong's trading occurring during London's overnight nontrading period.

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Table 3
Trade sizes in Hong Kong and London trading

Company name	Hong Kong trading (share)			London trading (share)			LSE/HK		
	Jan-1996	Feb-1996	Mar-1996	Jan-1996	Feb-1996	Mar-1996	Jan-1996	Feb-1996	Mar-1996
Cathay Pacific	16,861	15,660	13,650	89,618	84,453	145,061	5.32	5.39	10.63
Cheung Kong	7531	5527	5509	62,471	77,670	77,801	8.30	14.05	14.12
China Light & Power	7537	5955	5832	85,714	71,606	158,707	11.37	12.02	27.21
Citic Pacific	5230	4697	5754	101,867	49,093	61,187	19.48	10.45	10.63
Hang Lung	11,495	7672	8182	175,182	73,735	58,633	15.24	9.61	7.17
Henderson Land	5974	5568	5899	86,469	91,100	73,206	14.48	16.36	12.41
Hong Kong & China Gas	9321	9971	9817	217,979	204,251	128,131	23.39	20.48	13.05
Hong Kong Telecom	12,856	13,549	14,143	312,727	317,599	452,810	24.33	23.44	32.02
Hongkong Electric	11,111	7758	8736	125,050	96,258	101,940	11.25	12.41	11.67
HSBC	2518	2538	3172	116,052	90,247	65,054	46.09	35.55	20.51
Hutchison Whampoa	7247	6702	9081	89,480	107,042	70,066	12.35	15.97	7.72
Hysan Development	13,677	8977	9002	102,957	75,094	101,717	7.53	8.36	11.30
New World	6440	5471	5126	122,996	86,338	84,415	19.10	15.78	16.47
Sun Hung Kai	5589	5393	6364	64,585	48,837	56,538	11.56	9.06	8.88
Swire Pacific	6943	5382	5617	141,432	52,049	42,662	20.37	9.67	7.60
Wharf	8771	7811	9632	107,638	111,408	74,919	12.27	14.26	7.78
Wheelock	7679	8461	8322	65,110	66,756	54,007	8.48	7.89	6.49
Overall average	8634	7476	7873	121,607	100,208	106,285	15.93	14.16	13.27

Notes: The table presents the average trade sizes from London and Hong Kong trading for the 17 sample stocks that are traded in both Hong Kong and London during the three-month study period from January 1996 to March 1996.

starting point is to examine how closing price information from one market impacts the opening process in the other.

When the London market opens its trading at 9:30 AM, G.M.T., the most relevant piece of information should be the Hong Kong closing prices. Because the Hong Kong market closes 1.5 h before the London market officially starts trading, we expect London market participants to easily observe Hong Kong's closing price information. To take advantage of this setting, we compare closing bid and ask prices from Hong Kong with opening bid and ask quotations from the London market to test whether London market makers incorporate Hong Kong closing prices into their quotations. We calculate the distance between Hong Kong's closing bid price and London's opening bid price as well as between London's opening ask price and Hong Kong's closing ask price. We are interested in two specific patterns that would highlight the role of Hong Kong prices in determining London prices: (i) a positive distance which indicates that London market makers always set the bid price lower than Hong Kong's closing bid price and set the ask price higher than Hong Kong's closing ask price; and (ii) the equality between two distances, which indicates that London market makers deliberately use Hong Kong prices as the benchmark in determining their bid and ask quotes. If the two distances are asymmetric, it would imply that Hong Kong quotes are not utilized by London Market makers as reference prices.

Table 4 reports the 60-day study period summary statistics for the distance measures between the London opening and Hong Kong closing bid and ask quotes. In parentheses, *t*-statistics and number of London opens with positive distances are reported. An interesting regularity emerges. On average, the bid price quoted by London market makers at opening is lower than Hong Kong closing bid by the amount of HK$0.17. Furthermore, the number of trading days with positive

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Table 4
Distances of London open to Hong Kong close

Company name	Distance in asks (Hong Kong dollar)			Distance in bids (Hong Kong dollar)			*t*-Statistics (1) = (4)
	(1) Mean	(2) Min	(3) Max	(4) Mean	(5) Min	(6) Max	
Cathay Pacific	0.09 (8.21, 58)	−0.03	0.30	0.11 (9.85, 57)	−0.05	0.55	1.24
Cheung Kong	0.18 (4.61, 57)	−0.05	0.80	0.22 (5.57, 58)	−0.06	0.34	0.69
China Light & Power	0.21 (17.32, 60)	0.00	0.40	0.18 (16.48, 60)	0.00	0.40	1.59
Citic Pacific	0.18 (9.36, 58)	−0.08	0.50	0.21 (10.74, 60)	0.00	0.32	1.14
Hang Lung	0.11 (15.64, 57)	−0.05	0.25	0.12 (16.97, 59)	−0.01	0.25	1.06
Henderson Land	0.22 (10.22, 56)	−0.03	0.31	0.19 (9.55, 57)	−0.05	0.50	1.07
Hong Kong & China Gas	0.18 (5.03, 60)	0.05	0.72	0.18 (7.87, 58)	−0.03	0.36	0.86
Hong Kong Telecom	0.07 (6.03, 59)	−0.05	0.20	0.08 (6.90, 59)	−0.01	0.40	1.13
Hongkong Electric	0.19 (17.59, 60)	0.00	0.50	0.18 (17.38, 60)	0.05	0.45	0.12
HSBC	0.12 (6.19, 60)	0.00	0.29	0.21 (3.16, 59)	−0.02	0.50	1.95
Hutchison Whampoa	0.23 (11.56, 58)	−0.01	0.70	0.19 (10.88, 57)	−0.03	0.44	1.28
Hysan Development	0.24 (4.71, 60)	0.05	0.36	0.13 (2.44, 57)	−0.08	0.35	1.55
New World	0.19 (11.43, 60)	0.05	0.38	0.17 (9.69, 58)	−0.06	0.40	0.86
Sun Hung Kai	0.21 (8.95, 56)	−0.03	0.75	0.25 (14.59, 59)	−0.01	0.35	1.33
Swire Pacific	0.22 (11.71, 60)	0.00	0.55	0.24 (13.62, 59)	−0.01	0.40	0.91
Wharf	0.18 (15.14, 57)	−0.05	0.50	0.19 (13.16, 60)	0.00	0.55	0.80
Wheelock	0.15 (11.87, 60)	0.00	0.40	0.14 (12.69, 56)	−0.06	0.30	0.49
Overall average	0.17			0.18			

Notes: The table reports the 60-day study period summary statistics for the distance measures between the London opening and Hong Kong closing bid and ask quotes. Distance in asks is the difference in prices between London asks at opening and Hong Kong asks at closing. Distance in bids is the difference in prices between Hong Kong bids at closing and London bids at opening. The number of London opens with positive distances and *t*-statistics are reported in parentheses. The last column in the table reports *t*-statistics of testing the equality between distance in asks and distance in bids.

distances ranges from 56 to 60 days (or 93% to 100%) during the study period. Virtually identical results are observed for the differences between London and Hong Kong opening asks. London market makers set the ask price HK$0.18 more than the Hong Kong closing ask price and the positive differences are persistent, ranging from 57 to 60 trading days (or 95% to 100%). Interestingly, closing bid and ask prices from Hong Kong actually serve as the highest buy order and the lowest sell order in London; and London opening bid and ask prices represent the best bid and ask prices quoted by London market makers.

The last column in Table 4 reports the equality test results. As shown in the table, the equality of two distances (London opening bids vs. Hong Kong closing bids and London opening asks vs. Hong Kong closing asks) cannot be rejected for all 17 stocks in our sample. This unique, symmetric pattern is generally consistent with the notion that London market makers do take notice of Hong Kong closing price information when setting London open quotations.[12]

[12] It is a well established that, bid and ask spreads quoted by market makers in quote-driven markets tend to be greater than those in the order-driven markets (Huang and Stoll, 1996; Bessembinder and Kaufman, 1997; Barclay et al., 1999). The comparison of bid and ask spreads in London and Hong Kong indicates the same tendency. During the study period, we observe that the average London spread is more than three times greater than that of the Hong Kong spread. Therefore, it is not surprising that the bid and ask prices posted by London market makers at market opening envelop those in Hong Kong in most cases as shown in Table 4.

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3.2. London closing prices vs. Hong Kong opening prices

A natural follow-up question is "Do Hong Kong market participants consider the London closing prices as benchmark in determining the Hong Kong opening prices?" Unfortunately, we are unable to conduct the same set of analyses presented in Section 3.1 because Hong Kong's opening bid and ask quotes are not available. In the absence of Hong Kong's opening bid and ask quotes, however, we can slightly amend the methodology to compare the distance between Hong Kong's opening price and London's closing price (as measured by the midpoint of London bid and ask quotes) with the distance between Hong Kong's opening price and Hong Kong previous day's closing price (as measured by the midpoint of bid and ask quotes). Because the London closing prices are 11 h old when the Hong Kong market opens and Hong Kong's closing prices on the previous trading day are 18 h old, one should expect that London's closing prices should have a greater impact on Hong Kong's opening prices. If Hong Kong market incorporates London's closing prices in its opening prices, we would expect that Hong Kong's opening prices are closer to London's closing prices than Hong Kong's closing prices on the previous day.

Table 5 summarizes the distances between Hong Kong's opening and London's closing prices and those between Hong Kong's opening and Hong Kong's closing prices on the previous day. The average distance of Hong Kong's opening prices from Hong Kong's previous day closing prices is HK$0.22 while it is HK$0.21 for Hong Kong's opening and London's closing prices. With the exception of three stocks (HSBC, Hong Kong & China Gas, and Hong Kong Telecom), no significant differences are observed between the two distances for the remaining 14 stocks, which suggests that investors from Hong Kong may not pay too much attention to London's closing prices. It is consistent with the notion that London trades lack informational value; hence, they contribute little to price discovery in Hong Kong's opening.[13] The three exceptions, however, represent the stocks that are heavily traded in London. The three Hong Kong stocks with large trading volume in London support the conclusions of Grammig et al. (2004) that the greater the liquidity of New York trading relative to the home market, the greater the role of the New York market price discovery.

3.3. Hong Kong [London] overnight return vs. London [Hong Kong] trading return

Having demonstrated that London opening bids and asks consistently and uniformly envelop the closing bids and asks from the Hong Kong market with equal distances, we rely on two tests in order to confirm that Hong Kong price quotes are used as benchmark for London price quotes.

First, we estimate the percentage contribution Hong Kong's trading makes to London overnight price changes and vice versa. To estimate the mutual contributions, we use the weighted price contribution (WPC) introduced by Barclay and Warner (1993), Cao et al. (2000), and

[13] We conduct a similar test using London's opening price; its closing price on previous day; and Hong Kong's closing price to measure the distance between London's opening prices and Hong Kong's closing prices and those between London's opening prices and closing prices from the previous day. The results indicate that the distance between London's opening prices and Hong Kong's closing prices are significantly smaller than the distance between London's opening prices and London closing prices from the previous day. The result indicates that Hong Kong closing prices play a significant role in determining London's opening prices. Moreover, the result confirms the findings reported in Table 4. We would like to thank the referee for suggesting this robustness test.

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Table 5
Distances between Hong Kong opening and London closing/Hong Kong closing prices on previous day

Company name	Distance between Hong Kong opening and closing prices on previous day (Hong Kong dollar)	Distance between Hong Kong opening and London closing prices (Hong Kong dollar)	Difference (Hong Kong dollar)	*t*-Statistics
Cathay Pacific	0.081	0.087	−0.005	−0.46
Cheung Kong	0.401	0.392	0.003	−0.06
China light & power	0.195	0.231	−0.034	−0.36
Citic Pacific	0.181	0.142	0.044	1.32
Hang Lung	0.230	0.270	−0.040	−0.85
Henderson Land	0.368	0.374	−0.006	−0.15
Hong Kong & China Gas	0.182	0.090	0.092	2.89
Hong Kong Telecom	0.163	0.109	0.054	3.05
Hongkong Electric	0.114	0.109	0.009	0.47
HSBC	0.200	0.130	0.070	3.42
Hutchison Whampoa	0.271	0.294	−0.023	−0.65
Hysan Development	0.134	0.142	−0.007	−0.38
New World	0.203	0.194	0.010	0.37
Sun Hung Kai	0.363	0.350	0.012	0.18
Swire Pacific	0.372	0.326	0.046	0.90
Wharf	0.111	0.146	−0.035	−1.40
Wheelock	0.118	0.109	0.009	0.79
Overall average	0.217	0.206	0.012	

Notes: The table summarizes the distances between Hong Kong's opening and London's closing prices and those between Hong Kong's opening and Hong Kong's closing prices on the previous day. The difference test *t*-statistics are reported in the last column.

Chakravarty (2001). Specifically, we use following formula to measure the contribution by Hong Kong [London] day trading to London [Hong Kong] overnight price changes.

$$\mathrm{WPC} = \sum_{t=1}^{T} \left(\frac{|\Delta P_{\mathrm{N},t+1}|}{\sum_{t=1}^{T} |\Delta P_{\mathrm{N},t+1}|} \right) \times \left(\frac{\Delta P_{\mathrm{D},t}}{\Delta P_{\mathrm{N},t+1}} \right), \tag{1}$$

where $\Delta P_{\mathrm{N},t+1}$ is the Hong Kong (London) overnight price change on day $t+1$ (from day t close to day $t+1$ open) and $\Delta P_{\mathrm{D},t}$ is the London (Hong Kong) trading period return from market open to market close on day t.[14] The first term on the right-hand side of Eq. (1) is the weighting factor on each day and the second term is the contribution of the trading period price changes to the overnight price changes.

In the second test, we would like to confirm the absence of price reversals/continuations after the London market begins trading. After the London opening prices fully incorporate the Hong Kong closing prices, we would expect London trading not to exhibit any pattern of reversals or continuations since London trading is not information-driven. The Stoll and Whaley (1990, 1991, 1997) price reversal measure is a convenient tool for the test. Price reversals/continuations are measured as shown below:

[14] When London overnight price changes and Hong Kong trading period price changes are considered, the subscript $t+1$ is no longer needed because trading on the both markets occurs on the same day t.

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$$\mathrm{REV}_{o,t} = \begin{cases} R_{o,t} & \text{if } R_{co,t} < 0 \\ -R_{o,t} & \text{if } R_{co,t} \geq 0, \end{cases} \quad (2)$$

where $R_{co,t}$ is defined as the 1.5-h returns from Hong Kong market close to London market open on day t; and $R_{o,t}$ denotes the 2-h returns after the London market open on the same day.[15] Under this definition, a positive value for REV_o indicates a reversal and a negative REV_o value indicates a continuation. To avoid complications related to infrequent trading, we continue to use midpoints of bid and ask quotes for the computation of returns. We hypothesize that neither continuation nor reversal pattern would be exhibited for two reasons: first, the Hong Kong closing prices should be fully incorporated into London opening prices; and second, the London price discovery is not information-driven. Hence, we expect REV_o estimated for sample firms to be insignificant.

Panel A of Table 6 summarizes WPC as measured by Eq. (1). The first column reports the contribution of London day trading to Hong Kong overnight trading and the second column summarizes the contribution of Hong Kong day trading to London overnight returns. Large values of WPC are predominant in the second column across all stocks in our sample, ranging from 67% to 96%. The average WPC is 82%, implying that Hong Kong trading can explain a majority of the London overnight return. In other words, the Hong Kong trades explain a large portion of London overnight price changes. In contrast, WPC values for London day trading are small, on average only 18%, indicating London trading makes only a limited contribution to Hong Kong overnight price changes and that price changes from London trading provide little inference about where the prices in Hong Kong will move the next morning.

Panel B of Table 6 presents price continuations/reversals as measured by Eq. (2). With the exception of three companies (HSBC, Hong Kong Telecom, and Wharf), none of t-statistics computed for continuation/reversal measures are significant at the 5% level, which implies that once London opening prices incorporate Hong Kong closing prices, London price discovery exhibits no particular pattern in the absence of information-driven trading. However, the three companies cited above are those stocks with heavy London trading and it is possible that their price discovery in London differs from the rest of the Hong Kong stocks. The stocks with heavy London trading also tend to show higher WPC values.

3.4. Co-movement of London [Hong Kong] returns with Hong Kong [London] markets

Next, we examine the co-movement of stock returns of London [Hong Kong] with stock-market index movements of Hong Kong [London]. Previous studies have indicated that stock returns are affected by the market movements where they are traded (Bodurtha et al., 1995; Hardouvelis et al., 1995; Froot and Dabora, 1999; Bedi et al., 2003; De Jong et al., 2003; Chan et al., 2003; Gagnon and Karolyi, 2003). Our purpose is to investigate the role of the London and Hong Kong market portfolio returns in explaining the daily returns of the 17 stocks in our sample. We expect London returns to be affected by the Hong Kong market movements more than by the London market movements given that the Hong Kong market is where both public and private information is disclosed. Additionally, we expect Hong Kong trades of Hong Kong-listed stocks should be closely correlated with the Hong Kong market but not

[15] We have also investigated the returns at differing intervals (30-min, 1-h, and 1.5-h returns) after the London market begins trading. The results are consistent with what is presented in Panel B of Table 6.

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Table 6
Hong Kong [London] overnight return vs. London [Hong Kong] trading return

Panel A: contribution of overnight price discovery in Hong Kong and London trading

Company name	London daytime vs. Hong Kong overnight (%)	Hong Kong daytime vs. London overnight (%)
Cathay Pacific	26.63	79.53
Cheung Kong	27.07	77.12
China Light & Power	26.01	71.96
Citic Pacific	−17.91	84.67
Hang Lung	20.00	79.00
Henderson Land	13.38	95.71
Hong Kong & China Gas	38.54	67.19
Hong Kong Telecom	12.45	76.18
Hongkong Electric	35.14	78.93
HSBC	39.00	82.00
Hutchison Whampoa	27.30	76.61
Hysan Development	−11.61	71.88
New World	19.35	93.00
Sun Hung Kai	−6.67	90.92
Swire Pacific	24.93	90.14
Wharf	17.78	87.40
Wheelock	20.30	90.36
Overall average	18.33	81.92
Min	−17.91	67.19
Max	39.00	95.71

Panel B: price continuation/reversal

Company name	Mean (×10,000)	Std err (×10,000)	*t*-Statistics
Cathay Pacific	−6.35	7.53	−0.84
Cheung Kong	−1.91	5.34	−0.36
China Light & Power	9.41	6.88	1.37
Citic Pacific	−2.98	11.50	−0.26
Hang Lung	−2.32	6.78	−0.34
Henderson Land	9.12	8.54	1.07
Hong Kong & China Gas	11.00	13.63	0.81
Hong Kong Telecom	14.28	5.80	2.46
Hongkong Electric	−2.91	4.55	−0.64
HSBC	52.05	9.16	5.68
Hutchison Whampoa	−0.97	5.83	−0.17
Hysan Development	−13.32	19.58	−0.68
New World	−1.46	6.87	−0.21
Sun Hung Kai	−2.64	8.56	−0.31
Swire Pacific	0.55	4.90	0.11
Wharf	9.25	6.00	1.54
Wheelock	−7.48	6.53	−1.14

Notes: Panel A of Table 6 summarizes WPC as measured by Eq. (1). Mean, maximum and minimum of WPCs for sample stocks are also reported in the table.
Panel B of Table 6 presents price continuations/reversals as measured by Eq. (2). Means, standard errors of REV for sample stocks are reported in the first and second columns and *t*-statistics of testing price continuations/reversals are reported in the last column.

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with the London market movements since London trading is largely liquidity- rather than information-driven. We use the following regressions:

$$\mathrm{RET}^{\mathrm{LSE}}_{i,t} = \alpha_{0,i} + \alpha_{11,i}\mathrm{MRET}^{\mathrm{HK}}_{i,t} + \alpha_{12,i}\mathrm{MRET}^{\mathrm{HK}}_{i,t+1} + \alpha_{2,i}\mathrm{MRET}^{\mathrm{LSE}}_{i,t} + \alpha_{3,i}\mathrm{EXCH}_{i,t} + \varepsilon_{i,t}, \quad (3)$$

$$\mathrm{RET}^{\mathrm{HK}}_{i,t+1} = \beta_{0,i} + \beta_{1,i}\mathrm{MRET}^{\mathrm{HK}}_{i,t+1} + \beta_{21,i}\mathrm{MRET}^{\mathrm{LSE}}_{i,t} + \beta_{22,i}\mathrm{MRET}^{\mathrm{LSE}}_{i,t+1} + \beta_{3,i}\mathrm{EXCH}_{i,t} + \eta_{i,t}, \quad (4)$$

where $\mathrm{RET}^{\mathrm{LSE}}$ and $\mathrm{RET}^{\mathrm{HK}}$ are London and Hong Kong daily stock returns, respectively (computed using daily closing prices for Hong Kong and midpoints of daily closing bid and ask prices for London); $\mathrm{MRET}^{\mathrm{HK}}$ is the Hong Kong Hang Seng Index return; $\mathrm{MRET}^{\mathrm{LSE}}$ is the London FT 100 Index return; and EXCH denotes the exchange rates between HK$ and British pound. Even though London trading of Hong Kong stocks is conducted in Hong Kong dollars, we introduce an exchange rate variable to control the effects of exchange rate fluctuations since such fluctuations may impact international investors. Grammig et al. (in press) suggest that exchange rate innovations are important in explaining the New York price discovery of German stocks that are listed on the Frankfurt Stock Exchange.

Because $\mathrm{RET}^{\mathrm{LSE}}_{i,t}$ and $\mathrm{MRET}^{\mathrm{LSE}}_{i,t}$ are contemporaneous but $\mathrm{RET}^{\mathrm{LSE}}_{i,t}$ and $\mathrm{MRET}^{\mathrm{HK}}_{i,t}$ are not in Eq. (3), the regression model may assign an unfairly large weight to the London market index returns.[16] In order to mitigate this problem, we introduce $\mathrm{MRET}^{\mathrm{HK}}_{i,t+1}$ in Eq. (3). The co-movement of individual stock returns in London with the London market is measured by the coefficient α_2 while the co-movement of London returns with the Hong Kong market is measured by summing of coefficients α_{11} and α_{12}. Likewise, $\mathrm{RET}^{\mathrm{HK}}_{i,t+1}$ and $\mathrm{MRET}^{\mathrm{HK}}_{i,t+1}$ are contemporaneous but $\mathrm{RET}^{\mathrm{HK}}_{i,t+1}$ and $\mathrm{MRET}^{\mathrm{LSE}}_{i,t}$ are not in Eq. (4). Therefore, we introduce $\mathrm{MRET}^{\mathrm{LSE}}_{i,t+1}$ in the regression equation to control the overweighting of Hong Kong market index returns. The co-movement of individual stock returns in Hong Kong with the Hong Kong market is measured by the coefficient β_1 while the co-movement of Hong Kong returns with the London market is measured by summing of coefficients β_{21} and β_{22}.

Estimated regression results are summarized and reported in Table 7. In Panel A, we report Eq. (3) results which indicate that the impact of the Hong Kong and London market index returns on London returns of Hong Kong-listed stocks. As expected, among 17 stocks in our sample, only three stocks show statistically significant α_2. This indicates that London market index returns have little explanatory power over most stock returns from London trading. In contrast, 13 of 17 stocks have statistically significant α_{11}. Furthermore, 15 of 17 stocks have coefficient values of $\alpha_{11} + \alpha_{12}$ greater than their corresponding values for α_2. Above results suggest that these stock prices follow Hong Kong market movements more closely, even though they are being traded in London. Our findings contradict the observations by previous studies that stock returns are affected by the market movements where they are traded.

Panel B summarizes Eq. (4) results. High statistical significance is observed for the estimated coefficient of β_1 across all stocks in our sample, suggesting a very close correlation between stock returns from Hong Kong trading and Hong Kong market movements, which is expected. The co-movement between Hong Kong stock returns and London market index returns remains insignificant. The overall results are consistent with our predictions. Since Hong Kong is the home market for HKEx-listed stocks and their company core businesses are conducted in Hong Kong, trading in Hong Kong should be driven by public and private information. As a result, in the absence of significant and material private/public information

[16] We are grateful to the referee for alerting us of this possibility.

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Table 7
Regressions of stock returns from both Hong Kong and London trading on market returns of Hong Kong and London

Company name	Panel A					Panel B				
	α_0 ($\times 10^{-3}$)	α_{11}	α_{12}	α_2	α_3	β_0 ($\times 10^{-3}$)	β_1	β_{21}	β_{22}	β_3
Cathay Pacific	1.30 (0.51)	0.32 (1.79)	0.26 (1.60)	0.50 (1.49)	−0.84 (−1.02)	1.33 (0.61)	0.57*** (−3.42)	0.13 (0.33)	0.09 (0.24)	−0.37 (−0.54)
Cheung Kong	0.71 (0.41)	0.82*** (6.55)	0.10 (1.38)	0.24 (0.80)	−1.05 (−1.90)	0.60 (0.58)	1.25*** (15.74)	−0.43 (−1.35)	−0.14 (−0.77)	−0.75** (−2.27)
China Light & Power	−1.18 (−0.29)	0.49 (1.68)	0.21 (0.82)	0.10 (0.14)	−0.63 (−0.50)	−1.27 (−1.06)	0.80*** (8.67)	−0.05 (−0.25)	−0.03 (−0.16)	0.41 (1.06)
Citic Pacific	−0.18 (−0.09)	0.65*** (4.51)	0.37*** (2.96)	0.90 (1.79)	−1.44** (−2.25)	0.42 (0.24)	0.95*** (7.21)	0.37 (1.23)	0.23 (1.07)	−0.40 (−0.72)
Hang Lung	1.73 (0.70)	0.60*** (3.39)	0.17 (1.77)	0.71 (1.51)	−0.79 (−1.01)	1.56 (0.90)	0.97*** (7.25)	0.14 (0.45)	−0.03 (−0.10)	−0.46 (−0.83)
Henderson Land	0.72 (0.40)	0.81*** (6.22)	0.19 (1.64)	0.90 (1.76)	−0.79 (−1.36)	0.63 (0.49)	1.18*** (11.87)	0.24 (1.03)	−0.40 (−1.66)	−0.49 (−1.20)
Hong Kong & China Gas	2.68 (0.75)	0.40 (1.56)	0.28 (1.40)	0.59 (1.59)	−1.73 (−1.57)	2.99 (1.83)	0.61*** (4.85)	−0.15 (−0.53)	0.35 (1.18)	−0.12 (−0.23)
Hong Kong Telecom	1.35 (0.72)	0.23 (1.74)	0.13 (1.03)	0.95*** (2.91)	0.20 (0.33)	1.23 (0.78)	1.02*** (8.44)	−0.39 (−1.42)	0.05 (0.16)	0.81 (1.62)
Hongkong Electric	−0.57 (−0.43)	0.31*** (3.24)	0.10 (1.14)	0.34 (1.49)	0.02 (0.01)	−0.73 (−0.68)	0.61*** (7.36)	−0.16 (−0.85)	0.16 (0.82)	0.55 (1.59)
HSBC	−1.20 (−1.03)	0.67*** (6.33)	0.32 (1.13)	0.84*** (4.19)	−0.57 (−1.60)	−1.39 (−1.54)	0.69*** (7.67)	0.35** (2.15)	0.43** (2.44)	−0.34 (−1.21)
Hutchison Whampoa	−1.00 (−0.53)	0.67*** (4.92)	0.12 (0.97)	0.21 (0.64)	0.36 (0.60)	−0.87 (−0.59)	1.05*** (9.30)	−0.46 (−1.65)	−0.01 (−0.06)	0.78 (1.67)
Hysan Development	2.34 (1.35)	0.82*** (6.54	0.19 (1.70)	0.83 (1.89)	−0.17 (−0.32)	2.00 (1.35)	1.23*** (10.83)	0.20 (0.76)	0.26 (0.94)	0.15 (0.31)
New World	0.06 (0.03)	0.82*** (6.02)	0.28** (2.37)	0.58 (1.74)	0.49 (0.81)	0.31 (0.19)	1.15*** (8.28)	0.20 (0.62)	0.40 (1.18)	0.70 (1.20)
Sun Hung Kai	0.03 (0.01)	0.75*** (4.43)	0.12 (0.80)	0.52 (1.28)	−0.40 (−0.54)	−0.33 (−0.23)	1.20*** (11.04)	−0.13 (−0.52)	−0.53 (−1.01)	−0.37 (−0.81)
Swire Pacific	0.85 (0.44)	0.81*** (5.85)	0.07 (0.57)	0.65 (1.94)	0.73 (1.19)	0.95 (0.64)	1.26*** (10.94)	−0.13 (−0.50)	−0.45 (−1.63)	0.88 (1.84)
Wharf	0.62 (0.30)	0.73*** (4.94)	0.01 (0.03)	1.44*** (4.02)	0.27 (0.40)	0.71 (0.36)	1.22*** (8.01)	0.60 (1.70)	0.27 (1.29)	0.32 (0.51)
Wheelock	0.45 (0.24)	1.07*** (7.89)	0.02 (0.18)	0.80 (1.45)	−0.73 (−1.22)	0.24 (0.13)	1.43*** (10.32)	0.13 (0.41)	−0.12 (−0.37)	−0.22 (−0.39)

Notes: Panel A reports Eq. (3) results which indicate that the impact of the Hong Kong and London market index returns on London returns of Hong Kong-listed stocks. Panel B summarizes Eq. (4) results.

***Denotes statistically significant at the 1% level and **at 5% level.

generated during London trading hours, it is reasonable that price discovery in London largely depends on Hong Kong market trading activities. Our findings may appear inconsistent with what Gagnon and Karolyi (2003) compile. They show that returns on cross-listed international stocks have significantly higher systematic co-movements with U.S. market indexes and significantly lower systematic co-movements with home market indexes than their equivalent home-market shares. We believe, however, that this contradiction may be attributed to the absence of arbitrage barriers between Hong Kong and London while Gagnon and Karolyi's sample contains international stocks from 39 countries traded in the U.S. market and some countries may face information-based barriers that can impede arbitrage activities. In addition, some ADRs traded infrequently in New York tend to have high transaction costs which also impede arbitrage activities.

4. Summary and conclusions

The findings of this study show the asymmetric characteristics of Hong Kong and London trading, for the same stocks. Hong Kong trading predominantly determines price discovery in London, which is supported by the finding that the London opening prices closely follow Hong Kong's closing prices, and price changes during London overnight are almost perfectly explained by Hong Kong's daily trading. However, London trading has only a very small impact on price discovery in Hong Kong as illustrated by the evidence that London trading plays a very limited role in explaining Hong Kong overnight returns. Furthermore, both London trading and Hong Kong trading are affected by the Hong Kong market movements much more than by the London market movements.

More importantly, these results seem to suggest that London trades follow a free-rider pattern in terms of cross-market price discovery. Specifically, London market makers take advantage of price discovery in the Hong Kong market to satisfy the liquidity demands of London-based institutional investors.

The findings from this paper also raise the question of whether we need to re-interpret the pricing efficiency and segmentation of the cross-market trading. Though London trading plays only a trivial role in price discovery for Hong Kong cross-listed stocks, this evidence alone does not suggest that the pricing process between the two markets suffers from market inefficiency or that the trading processes are segmented. Without major complications from information-driven trading, nothing is unusual about the Hong Kong market serving as the primary price discovery market and the London market utilizing Hong Kong prices as benchmark prices for London trading.

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References

Bacidore, J.M., Sofianos, G., 2002. Liquidity provision and specialist trading in NYSE-listed non-U.S. stocks. Journal of Financial Economics 63, 133–158.

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Bae, K.H., Cha, B., Cheung, Y.L., 1999. The transmission of pricing information of dually-listed stocks. Journal of Business Finance and Accounting 26, 709–723.

Barclay, M.J., Christie, W., Harris, J., Kandel, E., Schultz, P., 1999. Effects of market reform on the trading costs and depth of Nasdaq stocks. Journal of Finance 54, 1–34.

Barclay, M.J., Warner, J.B., 1993. Stealth trading and volatility: which trades move prices? Journal of Financial Economics 34, 281–305.

Baruch, S., Karolyi, G.A., Lemmon, M.L., 2003. Multi-market trading and liquidity: Theory and evidence. Working Paper, Ohio State University.

Bedi, J., Richards, A., Tennant, P., 2003. The characteristics and trading behavior of dual-listed companies. Working Paper, Reserve Bank of Australia.

Bessembinder, H., Kaufman, H., 1997. A cross-exchange comparison of execution costs and information flow for NYSE-listed stocks. Journal of Financial Economics 46, 293–319.

Bodurtha, J., Kim, D., Lee, C., 1995. Closed-end country funds and U.S. market sentiment. Review of Financial Studies 8, 879–918.

Cao, C., Ghysels, E., Hatheway, F., 2000. Price discovery without trading: evidence from the Nasdaq preopening. Journal of Finance 55, 1339–1365.

Chakravarty, S., 2001. Stealth-trading: which traders' trades move stock prices. Journal of Financial Economics 61, 289–307.

Chan, K.C., Fong, W.G., Kho, B.C., Schultz, R.M., 1996. Information, trading, and market returns: lessons from dually-listed securities. Journal of Banking and Finance 20, 1161–1187.

Chan, K., Hameed, A., Lau, S.T., 2003. What if trading location is different from business location? Evidence from the Jardine Group. Journal of Finance 58, 1221–1246.

Chang, R.P., Oppenheimer, H., Rhee, S.G., 1997. The Offshore Migration of Trading of Hong Kong-Listed Stocks: Causes and Effects. Hong Kong Securities & Futures Commission, Hong Kong.

Chowdhry, B., Nanada, V., 1991. Multimarket trading and market liquidity. Review of Financial Studies 4, 483–511.

De Jong, A., Rosenthal, L., van Dijk, M., 2003. The limits of arbitrage: evidence from dual-listed companies. Working Paper, Erasmus University.

Ding, D.K., deB. Harris, F.H., 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, S.C., Sabherwal, S., 2003. Cross-border listings and price discovery: evidence from U.S. listed Canadian stocks. Journal of Finance 58, 549–575.

Froot, K., Dabora, E., 1999. How are stock prices affected by the location of trade? Journal of Financial Economics 53, 189–216.

Gagnon, L., Karolyi, G.A., 2003. Multi-market trading and arbitrage. Working Paper, Ohio State University.

Grammig, J., Melvin, M., Schlag, C., 2004. The role of U.S. trading in pricing internationally cross-listed stocks. Working Paper, Arizona Sate University.

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

Grossman, S.J., 1992. The informational role of upstairs and downstairs trading. Journal of Business 65, 509–528.

Hardouvelis, G., La Porta, R., Wizman, T., 1995. What moves the discount on country equity funds. Working Paper No. 4571, National Bureau of Economic Research, Cambridge, MA.

Huang, R., Stoll, H.R., 1996. Dealer versus auction markets: a paired comparison of execution costs on NASDAQ and the NYSE. Journal of Financial Economics 41, 313–357.

Kim, M., Szakmary, A.C., Mathur, I., 2000. Price transmission dynamics between ADRs and their underlying foreign securities. Journal of Banking and Finance 24, 1359–1382.

Neumark, D., Tinsley, P.A., Tosini, S., 1991. After-hours stock prices and post-crash hangovers. Journal of Finance 46, 159–178.

O'Hara, M., 1995. Market Microstructure Theory. Blackwell Publishers Ltd..

Stoll, H.R., Whaley, R.E., 1997. Expiration-day effects of the all ordinary share price index futures: empirical evidence and alternative settlement procedures. Australian Journal of Management 22, 139–174.

Stoll, H.R., Whaley, R.E., 1991. Expiration-day effects: what has changed? Financial Analysts Journal 47, 58–72.

Stoll, H.R., Whaley, R.E., 1990. Program trading and individual stock returns: ingredients of the triple witching brew. Journal of Business 63, 165–192.

Wang, S.S., Rui, O.M., Firth, M., 2002. Return and volatility of dually-traded stocks: the case of Hong Kong. Journal of International Money and Finance 21, 265–293.

Werner, I.M., Kleidon, A.W., 1996. U.K. and U.S. trading of British cross-listed stocks: an intraday analysis of market integration. Review of Financial Studies 2, 619–664.

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