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# The intraday patterns of the spread and depth in a market without market makers: The Stock Exchange of Hong Kong

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## Abstract

We examine the temporal behavior of the spread and depth for common stocks listed on the Stock Exchange of Hong Kong (SEHK), which operates as a purely order-driven mechanism. We find *U*-shaped intraday and intraweek patterns in the spread and reverse *U*-shaped patterns in the depth. Our finding is consistent with that of the study of Lee et al. (1993) [Lee, C.M.C., Mucklow, B., and Ready, M.J., 1993, Spreads, depths, and the impact of earnings information: an intraday analysis, *Review of Financial Studies* 6, 345–374] of New York Stock Exchange (NYSE) stocks that wide spreads are associated with small depths and narrow spreads are associated with large depths. The negative association between spread and depth on the SEHK implies that limit order traders actively manage both price and quantity dimensions of liquidity by adjusting the spread and depth. Further, larger spreads and narrower depths around the market open and close indicate a trading strategy by limit order traders to avoid possible losses from trading with informed traders when the adverse selection problem is severe. The paper provides further evidence that *U*-shaped spread and reverse *U*-shaped depth patterns should not be solely attributed to specialist market making activities. © 1999 Elsevier Science B.V. All rights reserved.

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## 1. Introduction

Nearly all North American stock markets depend on market makers for price-setting and to provide liquidity. For example, multiple dealers in the National Association of Securities Dealers Automated Quotation system (Nasdaq) or specialists in the New York Stock Exchange (NYSE) and the American Stock Exchange (Amex) assume a pivotal role in providing liquidity to the market. However, a trading system based on market makers is the exception rather than the rule outside North America. Only a few exchanges in continental Europe and none in Asia operate under this trading system. In fact, among the top 37 stock exchanges outside North America, only three use the market-maker system; the rest rely on the order-driven mechanism without designated market makers.<sup>1</sup> Even in trading systems that still rely on market makers, their dependence has been steadily diminished by the introduction of various computer-assisted trading systems that automatically match buy and sell orders.

Although the majority of the world exchanges have adopted the order-driven mechanism, the extant market microstructure literature has primarily focused on the market-maker system without paying much attention to the order-driven system. Only a few studies have so far empirically examined the order-driven trading mechanism,<sup>2</sup> and relatively little is known about its market microstructure.

In this paper, we examine the liquidity-provision role of limit order traders in an order-driven market using intraday data from the Stock Exchange of Hong Kong (SEHK). Specifically, we analyze the spread and depth patterns in the SEHK's limit-order system, compare them with those of the NYSE specialist system, and draw implications from the comparison.

The SEHK provides an ideal setting to examine the behavior of limit order traders for several reasons. First, the SEHK relies solely on limit-order placement. There are no market makers or floor traders with special obligations or differential access to trading opportunities. Second, the generated data fully capture the order flow and execution processes since the market is centralized and computerized. Third, the market is very transparent. There are no "hidden orders" that are invisible to traders unlike the limit order book of the Paris Bourse or the Stockholm Stock Exchange.<sup>3</sup> The order and trade information is instantaneously disseminated to the public through an electronic screen on a real-time basis.

Our primary finding is that the spread (measured in both quoted and effective spreads) in the limit-order book of the SEHK exhibits a U-shaped intraday pattern while the depth displays a reverse U-shape. The spread is largest at the market

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<sup>1</sup> Data from The 1994 Handbook of World Stock and Commodity Exchanges.

<sup>2</sup> These studies include Niemeyer and Sandås (1993) on the Stockholm Stock Exchange, Lehmann and Modest (1994) and Hamao and Hasbrouck (1995) on the Tokyo Stock Exchange, Biais et al. (1995) on Paris Bourse, and Hedvall et al. (1997) on the Finnish Stock Exchange.

<sup>3</sup> See Lehmann and Modest (1994) and Niemeyer and Sandås (1993) for details.

opening and declines almost monotonically throughout the trading day before it picks up slightly at the market close. Market depth, measured as the dollar amount of bid and ask orders submitted at the best (i.e. inside) bid and offer prices, on the other hand, shows the opposite pattern. It is lowest at the opening and then rises monotonically until the close, at which point it suddenly drops. We also identify a similar U-shaped intraweek pattern in the spread and a reverse U-shaped intraweek pattern in the depth. The bid–ask spread (depth) is lowest (largest) on Tuesdays and Wednesdays and highest (smallest) on Fridays.

The generally negative relation between spread and depth on the SEHK limit-order book is consistent with findings in the NYSE by Lee et al. (1993) — that wide spreads are associated with small depths, and narrow spreads are associated with large depths. The negative correlation between spread and depth is most pronounced on the market opening and close, and remains significant even after we control for the intraday effects. This negative association implies that limit order traders actively manage both price and quantity dimensions of liquidity by adjusting the spread and depth.

The intraday and intraweek spread and depth patterns in the SEHK are broadly consistent with information asymmetry models of market microstructure (Copeland and Galai, 1983; Glosten and Milgrom, 1985; Easley and O'Hara, 1987; Foster and Viswanathan, 1990, among others). These models predict that greater information asymmetry between informed traders and uninformed liquidity providers leads to wider spreads and lower depths as uninformed liquidity traders attempt to minimize losses from trading with informed traders. According to Glosten (1994), discretionary uninformed traders who act as liquidity providers are more likely to choose limit orders than market orders. As long as limit order traders have an informational disadvantage relative to informed traders, the adverse selection problem is likely to be more serious around the market open and close, due to concentrated informed trading around these periods.<sup>4</sup> Thus, limit order traders are likely to maintain wider spreads and lower depths in order to avoid losses from trading with the informed. Likewise, around the beginning and the end of the week, the spread could be wider and the depth smaller for the same reason.

The trading pattern of limit order traders on the SEHK is similar to the quote-posting behavior of the specialist on the NYSE, as documented by Foster and Viswanathan (1993), Lee et al. (1993), and McNish and Wood (1992), among others. Our results suggest that the intraday U-shaped spread and the reverse U-shaped depth patterns are not solely attributable to specialists' market-making behavior, as many microstructure studies assume. Specialist participation on the

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<sup>4</sup> Foster and Viswanathan (1993) find that adverse selection costs are higher at the market open and close on the NYSE.

NYSE is typically less than 20% of the total volume.<sup>5</sup> The remaining volume is the result of public and member firms' orders meeting directly. In a recent study, Chung et al. (1999) suggest that the U-shaped intraday spread pattern on the NYSE represents the trading behavior of limit order traders rather than that of specialists. Our paper also provides evidence suggesting that limit-order trading alone produces the U-shaped intraday pattern of spreads.

The paper is organized as follows: Section 2 describes the SEHK trading mechanism and the data, Section 3 presents empirical finding, and Section 4 concludes.

## 2. Description of the market and the dataset

### 2.1. Structure of the Stock Exchange of Hong Kong

The SEHK is a limited company owned by its member brokers. In terms of market capitalization, it forms the seventh largest equity market in the world and is the second largest in Asia after the Tokyo Stock Exchange.<sup>6</sup> The SEHK has a single main board: There is currently no second section, nor an OTC market. Trading is carried out on the exchange floor in two sessions each day — from 10:00 to 12:30, and from 14:30 to 15:55<sup>7</sup> — on weekdays (excluding Saturdays and public holidays).

Trading is conducted through terminals in the Exchange's trading hall, and also (since January 25, 1996) through terminals at the members' offices. Investors place orders in the computerized market through brokers. Share trading originates from an investor order in the form of either a market order or limit order, but the trading system only accepts limit orders.

Orders are executed through an automated trading system, known as the Automatic Order Matching and Execution System (AMS), which is a computerized limit-order driven trading system. All brokers are directly connected to the AMS system. The AMS displays the five best bid and ask prices, along with the broker identity (broker code) of those who submit orders at the respective bid/ask prices being shown, and the number of shares demanded or offered at each of the five bid and ask queues. The AMS currently supports both automatic order matching and the manual execution method. Under this dual operational mode, all securities are traded through the AMS and are divided into two categories; automatch stocks and non-automatch stocks. As of March 1997, all stocks traded

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<sup>5</sup> For example, specialists participated in 17% of the NYSE volume traded in 1994 (The 1994 NYSE Fact Book).

<sup>6</sup> The comparison is based on the statistics at the end of 1996. (Source: The 1996 Stock Exchange of Hong Kong Fact Book)

<sup>7</sup> There is no afternoon trading session on the eves of New Year and Lunar New Year.

Table 1  
Frequency distributions of trade types

Trade type	No. of trades in 1000	Share volume in million	Dollar volume in HK\$ million
Automatched	6695 (97.7%)	229,558 (88.9%)	792,933 (85.9%)
Manual	47 (0.7%)	5193 (2.0%)	22,536 (2.4%)
Semi-odd	0 (0.0%)	2 (0.0%)	6 (0.0%)
Special	30 (0.4%)	12,463 (4.8%)	59,917 (6.5%)
Special-odd	80 (1.2%)	10,881 (4.2%)	44,508 (4.8%)
Overseas	5 (0.0%)	206 (0.1%)	3766 (0.4%)
Total	6852 (100.0%)	258,303 (100.0%)	923,670 (100.0%)

This table presents the frequency distributions of six trade types in number of trades, share volume, and dollar volume. The respective percentage frequencies of individual trade types are reported in parentheses. The sample consists of common stocks listed on the Stock Exchange of Hong Kong during the six-month period between October 1, 1996 and March 27, 1997.

on the SEHK were registered for automatching through the AMS (although this system also permits them to be traded manually).

Orders in automatch stocks are executed on a strict price and time priority basis. Orders are matched in the order in which they are entered into the AMS, based on the best price. An order entered into the system at an earlier time must be executed in full before an order at the same price, but entered at a later time, can be executed. An order with a price equal to the best opposite order will match with opposite orders at the best price queue in the system, one by one according to time priority. The maximum order size for automatch stocks is 200 board lots.<sup>8</sup> The queue position in the system is maintained until the order is either completely filled or canceled, or the end of the trading day, whichever comes first. At the end of the trading day, all orders are purged from the AMS.

Table 1 reports the frequency distributions of the number, share volume, and dollar volume of all transactions of all stocks traded on the SEHK between October 1, 1996 and March 27, 1997. The SEHK classifies each trade as one of the following: automatch, manual, semi-odd, special, special-odd, or overseas. Table 1 shows that the percentage of automatched trades is 97.7%. Automatched share and dollar volumes represent 88.9% and 85.9% of all transactions, respectively.<sup>9</sup>

The SEHK maintains a finer tick size schedule than any other major stock exchange in the world. The SEHK tick size is a step function of the stock price: Each stock traded is assigned a tick size, which represents the permissible price increments, at which the stock may be quoted, and deals struck. The SEHK has

<sup>8</sup> On the SEHK, the board lot size (the generally accepted unit of trading on the exchange) is not uniform across firms. Each firm chooses its own lot size.

<sup>9</sup> Since orders exceeding the size limit of 200 board lots are to be traded manually, the percentages of share and dollar volume of transactions are lower.

Table 2

Tick sizes by stock price

Price range (in HK\$)	Tick size (HK\$)
0.01–0.25	0.001
0.25–0.50	0.005
0.50–2.00	0.010
2.00–5.00	0.025
5.00–30.00	0.050
30.00–50.00	0.100
50.00–100.00	0.250
100.00–200.00	0.500
200.00–1000.00	1.000
1000.00 and over	2.500

This table presents the exchange-mandated minimum price variations across ten different price ranges in the Stock Exchange of Hong Kong.

probably the most extreme version of a step function, with ten different tick sizes. Table 2 reports the tick sizes across different price levels. Tick size ranges from HK\$0.001 for securities with share prices between HK\$0.01 and HK\$0.25, to HK\$2.50 for securities with share prices over HK\$1000.

## 2.2. Data

Our data sources for this study are the *Trade Record* and the *Bid and Ask Record*, both published by the SEHK. The *Trade Record* data set includes all transaction prices and volume records with a time stamp recorded to the nearest second. The *Bid and Ask Record* contains intraday bid–ask information recorded at 30-second intervals. The *Bid and Ask Record* shows limit-order prices, order quantity, and the number of orders in the same queue up to five queues. All information in our data set is available to market participants in real time through the computerized information dissemination system. We use the six-month period from October 1, 1996 to March 27, 1997. We include only common stocks. We eliminate from our sample any stock with fewer than 60 listing days during that six-month period. We also drop firms priced below HK\$0.25 or above HK\$100. Our final sample comprises 471 common stocks.

Table 3 reports the cross-sectional averages of price levels, daily number of trades, share volume, and dollar turnover. Columns 1 and 2 show the price ranges and the number of stocks traded in each price range.<sup>10</sup> Most stocks trade in the range of HK\$0.50 and HK\$5. The average stock price is HK\$5.47, which is quite low compared with average stock price levels in other markets. For example, the

<sup>10</sup> The classification of the price range for each stock is based on the average price of the stock over the six-month sample period.

Table 3  
Summary statistics of price, daily number of trades, share volume, and dollar turnover

Price range (HK\$)	<i>N</i>	Price	Daily number of trades	Daily share volume (1000 shares)	Daily turnover (HK\$1000)
0.25–0.50	54	0.37 (0.01) <i>0.37</i>	102.11 (19.46) <i>53.84</i>	9163 (2083) <i>3299</i>	3748 (879) <i>1595</i>
0.50–2	196	1.10 (0.03) <i>1.07</i>	85.62 (8.92) <i>43.74</i>	4241 (575) <i>1657</i>	4739 (569) <i>1817</i>
2–5	118	3.01 (0.07) <i>2.78</i>	112.57 (14.89) <i>54.91</i>	4010 (569) <i>1891</i>	11,941 (1745) <i>5461</i>
5–30	82	11.30 (0.65) <i>9.98</i>	128.33 (17.45) <i>60.56</i>	2309 (429) <i>865</i>	23,245 (3629) <i>9396</i>
30–50	12	35.39 (1.54) <i>34.51</i>	303.49 (97.83) <i>95.86</i>	2075 (645) <i>692</i>	78,520 (25,641) <i>27,312</i>
50–100	9	70.43 (4.86) <i>69.45</i>	355.33 (85.55) <i>468.81</i>	2361 (650) <i>2974</i>	169,885 (44,523) <i>205,680</i>
All	471	5.47 (0.53) <i>1.79</i>	112.40 (7.41) <i>52.28</i>	4320 (383) <i>1712</i>	14,686 (1742) <i>3041</i>

This table reports the cross-sectional means, standard errors (in parentheses), and medians (in italics) for price, daily number of trades, daily share volume, and daily turnover for 471 common stocks listed on the Stock Exchange of Hong Kong. Stocks with the average price below HK\$0.25 or above HK\$100 are not included in the sample. For a given stock, the statistics are calculated for the six-month period from October 1, 1996 to March 27, 1997.

average price of the NYSE stocks is over US\$30. If we apply the fixed Hong Kong to US currency exchange rate of 7.8, the SEHK mean price of HK\$5.47 is equivalent to approximately US\$0.70.

Table 3 also shows that the average and median daily number of trades are 112 and 52, respectively. The daily number of trades generally increases with stock price, suggesting that high-priced stocks tend to be more liquid. The average daily volume is 4.3 million shares. The average dollar turnover for all stocks is HK\$14.7 million.

### 3. Empirical evidence

In this section, we examine the empirical evidence on the temporal variations of the spread, depth, and trading volume in the SEHK limit order book. We also compare the SEHK findings with documented facts on the NYSE market microstructure.

#### 3.1. Spreads

Table 4 presents the cross-sectional means, standard errors (in parentheses), and medians (in italics) of the quoted and effective spreads both in Hong Kong dollars and in the percentage of stock price. The quoted spread is defined as the best ask price minus the best bid price on the book. The average and median dollar quoted spreads for the entire sample are HK\$0.044 and HK\$0.026, respectively. The average dollar quoted spreads across different price levels are about two times larger than the corresponding tick sizes. The average and median percentage

Table 4  
The average quoted and effective spreads

Price range	Quoted spread		Effective spread			
	(HK\$)	HK\$	% Price		HK\$% Price	
0.25–0.50	0.011 (0.001) <i>0.009</i>	2.920 (0.162) <i>2.453</i>	0.005 (0.000) <i>0.005</i>	1.911 (0.092) <i>1.732</i>		
0.50–2	0.020 (0.001) <i>0.016</i>	1.955 (0.066) <i>1.692</i>	0.010 (0.000) <i>0.010</i>	1.447 (0.039) <i>1.324</i>		
2–5	0.042 (0.002) <i>0.034</i>	1.437 (0.053) <i>1.253</i>	0.025 (0.001) <i>0.024</i>	1.138 (0.039) <i>1.073</i>		
5–30	0.086 (0.004) <i>0.068</i>	0.956 (0.059) <i>0.856</i>	0.052 (0.002) <i>0.050</i>	0.744 (0.038) <i>0.730</i>		
30–50	0.161 (0.017) <i>0.138</i>	0.448 (0.047) <i>0.414</i>	0.111 (0.006) <i>0.105</i>	0.363 (0.022) <i>0.350</i>		
50–100	0.389 (0.082) <i>0.264</i>	0.594 (0.142) <i>0.413</i>	0.266 (0.008) <i>0.259</i>	0.474 (0.054) <i>0.415</i>		
All	0.044 (0.003) <i>0.026</i>	1.733 (0.046) <i>1.426</i>	0.027 (0.002) <i>0.013</i>	1.275 (0.028) <i>1.130</i>		

This table reports cross-sectional means, standard errors (in parentheses), and medians (in italics) for the dollar as well as percentage quoted and effective spreads for 471 common stocks listed on the Stock Exchange of Hong Kong. Stocks priced below HK\$0.25 or above HK\$100 are not included in the sample. For a given stock, the statistics are calculated for the six-month period from October 1, 1996 to March 27, 1997.

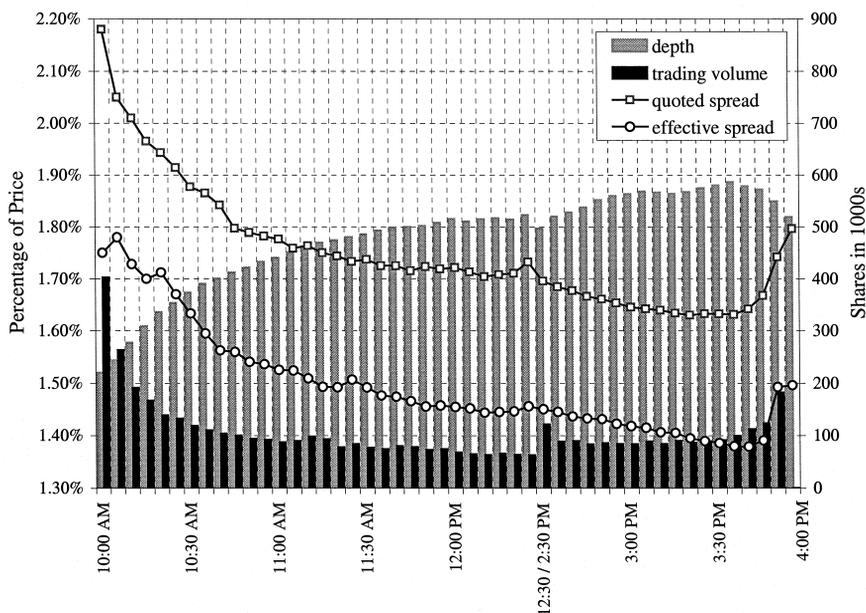


Fig. 1. Intraday patterns of percentage quoted and effective spreads, depths and volume.

quoted spreads are 1.73% and 1.43%. As the price level increases, the percentage quoted spread decreases from 2.92% for the lowest-priced stocks to 0.59% for the highest-priced stocks. The mean percentage spread of 1.73% on the SEHK seems to be significantly higher than the average bid–ask spread on the NYSE, which is around 0.6%.<sup>11</sup> This discrepancy could be due to differences in the average stock prices, liquidity characteristics of the listed stocks, or different institutional features of the two exchanges.

The effective spread for a round trip trade is defined as

$$ES = 2|p_t - q_t|, \quad (1)$$

where  $p_t$  is the transaction price at time  $t$ , and  $q_t$  is the midpoint of the bid and ask quotes recorded nearest to  $t$ . As we expected, the effective spread on the SEHK is much smaller than the quoted bid–ask spread. The mean dollar (percentage) effective spread for the entire sample is \$0.027 (1.28%). The median dollar (percentage) effective spread is \$0.013 (1.13%).

Fig. 1 shows the 5-minute intraday patterns of the percentage quoted and effective spreads, market depth, and trading volume. The market depth and trading volume are measured in number of shares. Both quoted and effective spreads

<sup>11</sup> The average NYSE spread figure is from The 1994 NYSE Fact Book.

exhibit U-shaped intraday patterns over the trading day. Both spreads reach their peak when the market opens and then fall during the rest of the day, picking up again during the last 15-minute trading session. Trading volume also exhibits a similar U-shaped intraday pattern. However, the depth displays a reverse U-shaped pattern. The depth increases during the trading day, reaching a peak at 3:35 PM before it declines. The Exchange’s lunch break seems to affect the variables. The spread and trading volume (depth) show an increase (a decrease) at the first 5 minutes of the afternoon session (2:30 to 2:35 PM).<sup>12</sup> The magnitudes of the changes however are relatively small.

Fig. 1 clearly shows systematic relations among the spread, volume, and depth on the SEHK. The spread, measured by the quoted as well as effective spreads, is positively associated with trading activity. At the same time, the spread is negatively associated with the depth. The combination of a wider spread and smaller depth around the open and the close of the SEHK implies a decrease in liquidity around these periods. Lee et al. (1993) report similar patterns on the NYSE. They report U-shaped intraday patterns of spreads and trading volume and a reverse U-shaped pattern of depth on the NYSE. A detailed discussion of the negative relation between spread and depth on the SEHK is provided later in Section 3.4.

To corroborate statistically the evidence of intraday spread pattern, we estimate a dummy-variable regression model following Lehmann and Modest (1994):

$$\text{spread}_{i,t} = \alpha + \sum_{h=1}^{10} \beta_h \text{dmktval}_{h,t} + \sum_{j=1}^5 \gamma_j \text{dweek}_{j,t} + \sum_{l=1}^8 \theta_l \text{dtime}_{l,t} + \varepsilon_{i,t},$$

$$\text{subject to } \sum_{h=1}^{10} \beta_h = 0, \quad \sum_{j=1}^5 \gamma_j = 0, \quad \text{and } \sum_{l=1}^8 \theta_l = 0, \quad (2)$$

where  $\text{spread}_{i,t}$  denotes the average percentage quoted or effective spread of stock  $i$  for a half-hour trading interval  $t$ , and  $\varepsilon_{i,t}$  is a random error with the usual normality properties. The dummy variables,  $\text{dmktval}$ ,  $\text{dweek}$ , and  $\text{dtime}$  denote the firm size, day of the week, and time of the day, respectively. The dummy variables take the value of one if the observation of the dependent variable belongs to the relevant group, and zero otherwise. The Greek symbols denote the parameters to be estimated. Since the explanatory variables consist of linearly dependent dummy variables, we impose the constraint that all within-group coefficients should total zero.

Table 5 reports the estimation results of the dummy-variable regression. The  $t$ -statistics are based on the White heteroskedasticity-consistent standard errors. The average quoted spread across all stocks, all time intervals, and all days is

<sup>12</sup> The increases in spreads and volume around the lunch break are consistent with the W-shaped intraday pattern of return volatility on the SEHK documented by Cheung et al. (1994).

Table 5  
Spread dummy variable regression results

Variable	Quoted spread		Effective spread	
	Coefficient	<i>t</i> -statistic	Coefficient	<i>t</i> -statistic
Intercept	1.73	748.30	1.23	490.28
dmktval <sub>1</sub> (smallest)	2.02	145.10	0.98	63.27
dmktval <sub>2</sub>	0.97	106.72	0.52	56.88
dmktval <sub>3</sub>	0.35	51.65	0.26	39.23
dmktval <sub>4</sub>	0.06	9.02	0.08	13.76
dmktval <sub>5</sub>	−0.01	−2.58	0.07	11.18
dmktval <sub>6</sub>	−0.30	−61.77	−0.12	−24.27
dmktval <sub>7</sub>	−0.30	−58.37	−0.18	−35.38
dmktval <sub>8</sub>	−0.67	−183.14	−0.33	−90.76
dmktval <sub>9</sub>	−0.90	−282.57	−0.52	−164.44
dmktval <sub>10</sub> (largest)	−1.22	−448.94	−0.75	−270.57
Monday	0.00	−0.13	0.01	3.81
Tuesday	−0.02	−4.91	0.00	1.13
Wednesday	−0.02	−4.06	−0.01	−3.43
Thursday	0.00	0.61	−0.01	−2.48
Friday	0.03	8.09	0.00	0.89
10:00–10:30 AM	0.32	51.78	0.06	8.22
10:30–11:00 AM	0.11	19.75	0.03	6.16
11:00–11:30 AM	0.01	1.51	−0.01	−0.95
11:30–12:00 AM	−0.05	−9.88	−0.03	−6.70
12:00–12:30 PM	−0.05	−10.03	−0.04	−8.77
2:30–3:00 PM	−0.14	−28.28	−0.01	−2.45
3:00–3:30 PM	−0.17	−34.77	−0.03	−6.04
3:30–3:55 PM	−0.02	−4.18	0.03	6.11
Adj. <i>R</i> <sup>2</sup>		0.31		0.17

The dependent variables used in the regression are the average percentage quoted spread and average percentage effective spread, both measured during the 30-minute intraday interval. All within-group dummy variable coefficients are restricted so that they total zero in order to avoid linear dependency among the independent variables. The *t*-statistics are based on the White heteroskedasticity consistent standard errors.

1.73%. The average effective spread is 1.23%. Both the quoted and effective spreads decrease monotonically as firm size increases. Averages of the quoted spread (effective spread) range from 0.51% (0.48%) for the largest stocks to 3.75% (2.21%) for the smallest stocks.

The weekday dummy coefficients indicate that the spread is lower during the middle of the week. The average quoted spread is highest (1.76%) on Fridays and lowest (1.71%) on Tuesdays and Wednesdays. The average effective spread is highest (1.24%) on Mondays and lowest (1.22%) on Wednesdays and Thursdays. The intraweek spread pattern documented on the SEHK is consistent with the U-shaped intraweek pattern documented for the NYSE (Foster and Viswanathan, 1993; McInish and Wood, 1992).

Coefficients of the intraday dummy variables clearly show a U-shaped intraday variation in the spread. Both the quoted and effective spreads are highest during the first half-hour of the trading session, averaging 2.05% for the quoted spread and 1.29% for the effective spread across all stocks. Both spreads decline after the first half-hour, reaching their lowest level (1.56% for the quoted spread and 1.20% for the effective spread) just before the last half-hour of trading. During the last half-hour of trading, however, the quoted spread increases by 0.15% to 1.71% and the effective spread increases by 0.06% to 1.26%.

The spread pattern reflected in the SEHK order book is virtually identical to the bid–ask spread pattern quoted on the NYSE. McInish and Wood (1992), Foster and Viswanathan (1993), and Chung et al. (1999) document a similar U-shaped intraday pattern of the NYSE spread. In particular, Chung et al. (1999) suggest that the U-shaped intraday spread pattern on the NYSE is attributable to the trading behavior of limit order traders rather than that of specialists. They find that spreads established by limit order traders exhibit a rise both at the open and the close, while spreads by specialists are widest at the open and level off during the rest of the day. The results in Table 5 also suggest that limit-order trading alone produces the U-shaped intraday pattern of spreads.

### *3.2. Depth*

Most studies on the intraday behavior of market microstructure focus on the spread alone. However, the spread is only one dimension of liquidity. Liquidity has both the price aspect (i.e., the spread) and the quantity aspect (i.e., the depth). For example, on the NYSE, one-half of all quote changes made by specialists involve only depth changes. Hence, we need to look at both spread and depth to fully understand the behavior of liquidity providers.

Table 6 presents the results of dummy-variable regressions in which we use market and cumulative depths as dependent variables. The market depth is the sum of the dollar amounts of the buy and sell orders submitted at the best bid and offer prices. The cumulative depth is the sum of the dollar amounts of orders at the five queues on both sides of the book. We average both depth measures during each half-hour interval. Then, we log-transform them because of skewness in their distributions. Other than for dependent variables, the model specification is identical to that for the spread dummy regression documented in the previous section.

The average market depth and cumulative depth across all stocks, all time intervals, and all days are 6.18 and 7.85, respectively. When transformed back to HK dollars, the intercepts of 6.18 for market depth and 7.85 for cumulative depth are equivalent to HK\$483,000 and HK\$2,566,000, respectively. Market depth increases monotonically as the firm size increases. The coefficients of the firm-size dummy variable range from 4.33 for the largest stocks to  $-2.25$  for the smallest stocks. Cumulative depth also exhibits a similar positive relation to firm size.

Table 6  
Depth dummy variable regression results

Variable	Market depth		Cumulative depth	
	Coefficient	<i>t</i> -statistic	Coefficient	<i>t</i> -statistic
Intercept	6.18	2123.25	7.85	2925.32
dmktval <sub>1</sub> (smallest)	−2.25	−188.31	−2.21	−202.63
dmktval <sub>2</sub>	−1.86	−201.58	−1.80	−207.50
dmktval <sub>3</sub>	−1.65	−201.33	−1.61	−211.28
dmktval <sub>4</sub>	−1.04	−137.23	−0.99	−140.54
dmktval <sub>5</sub>	−0.91	−110.61	−0.89	−117.00
dmktval <sub>6</sub>	−0.06	−7.43	−0.01	−0.87
dmktval <sub>7</sub>	0.26	30.18	0.25	31.96
dmktval <sub>8</sub>	1.17	153.04	1.12	163.69
dmktval <sub>9</sub>	2.00	275.53	1.89	287.08
dmktval <sub>10</sub> (largest)	4.33	521.06	4.22	543.74
Monday	−0.01	−0.92	−0.02	−3.28
Tuesday	0.03	4.55	0.01	1.01
Wednesday	0.03	5.16	0.03	6.28
Thursday	−0.02	−3.20	0.00	−0.25
Friday	−0.03	−5.46	−0.02	−3.66
10:00–10:30 AM	−0.20	−21.93	−0.18	−20.93
10:30–11:00 AM	−0.07	−8.77	−0.08	−10.40
11:00–11:30 AM	0.01	0.86	−0.01	−1.92
11:30–12:00 AM	0.04	5.71	0.03	3.83
12:00–12:30 PM	0.03	4.43	0.04	6.53
2:30–3:00 PM	0.10	14.33	0.07	10.37
3:00–3:30 PM	0.14	20.55	0.10	15.37
3:30–3:55 PM	−0.05	−7.70	0.03	4.69
Adj. <i>R</i> <sup>2</sup>		0.72		0.75

The dependent variables used in the regressions are market depth and cumulative depth, both in HK\$1000, over the five best queues on both sides of the order book measured during the 30-minute intraday interval. The dependent variables are log-transformed. All within-group dummy variable coefficients are restricted to total zero in order to avoid linear dependency among the independent variables. The *t*-statistics are based on the White heteroskedasticity consistent standard errors.

In Table 6, depth displays the opposite intraday pattern to spread, following a reverse U-shaped pattern during the trading day. Market depth (cumulative depth) is lowest during the first half-hour of the trading session with a coefficient of −0.20 (−0.18). Depth rises, reaching its highest level during the 30-minute interval just before the last half-hour trading period of the afternoon session. During the last half-hour of trading, depth decreases. Lee et al. (1993) report depth to display a reverse pattern of the spread. Our results also confirm that the intraday pattern of the depth is a reverse image of the spread. Overall, the intraday patterns of spread and depth indicate that liquidity on the SEHK is lowest around market open and close and highest during the middle of the trading day.

Finally, the weekday dummy coefficients also exhibit a reverse U-shaped pattern. Market depth is low at the beginning and the end of the week. This is consistent with the finding that on the NYSE liquidity is lowest on Mondays and Fridays and highest during the middle of the week. The regression result on weekday dummies using cumulative depth as the dependent variable is similar to the result using market depth as the dependent variable.

### 3.3. Trading activities

Table 7 reports estimation results of the dummy-variable regression models of trading activity measures. The dependent variables are the number of transactions,

Table 7  
Number of trades, dollar volume, and trade size dummy variable regression results

Variable	Number of trades		Dollar volume		Trade size	
	Coefficient	<i>t</i> -statistic	Coefficient	<i>t</i> -statistic	Coefficient	<i>t</i> -statistic
Intercept	2.36	794.16	6.19	1709.08	3.84	2670.33
dmktval <sub>1</sub> (smallest)	-0.58	-47.78	-1.18	-75.18	-0.60	-91.75
dmktval <sub>2</sub>	-0.40	-40.38	-0.88	-72.72	-0.48	-102.00
dmktval <sub>3</sub>	-0.17	-19.06	-0.65	-62.88	-0.49	-125.57
dmktval <sub>4</sub>	-0.20	-24.57	-0.48	-47.86	-0.28	-72.43
dmktval <sub>5</sub>	-0.07	-7.84	-0.33	-32.08	-0.26	-65.69
dmktval <sub>6</sub>	-0.10	-12.75	-0.07	-7.83	0.02	6.01
dmktval <sub>7</sub>	-0.17	-21.85	-0.07	-7.11	0.10	23.60
dmktval <sub>8</sub>	0.34	43.53	0.58	65.11	0.24	69.47
dmktval <sub>9</sub>	0.34	46.10	0.83	93.38	0.48	133.88
dmktval <sub>10</sub> (largest)	1.01	170.58	2.27	292.43	1.26	359.71
Monday	0.00	-0.06	0.00	-0.39	0.00	-0.84
Tuesday	-0.01	-0.97	-0.01	-1.06	0.00	-0.67
Wednesday	-0.01	-1.22	0.00	-0.07	0.01	2.23
Thursday	0.01	2.36	0.01	2.12	0.00	0.48
Friday	0.00	-0.15	0.00	-0.62	0.00	-1.22
10:00–10:30 AM	0.24	25.52	0.28	24.91	0.04	8.62
10:30–11:00 AM	0.09	11.44	0.08	8.36	-0.01	-3.08
11:00–11:30 AM	-0.08	-11.21	-0.11	-12.95	-0.03	-9.19
11:30–12:00 AM	-0.20	-29.83	-0.23	-27.55	-0.03	-8.03
12:00–12:30 PM	-0.30	-44.02	-0.32	-38.34	-0.03	-7.22
2:30–3:00 PM	0.06	8.55	0.03	3.88	-0.03	-7.70
3:00–3:30 PM	0.00	-0.21	0.02	2.54	0.02	6.52
3:30–3:55 PM	0.19	30.96	0.26	33.12	0.07	19.64
Adj. <i>R</i> <sup>2</sup>		0.15		0.35		0.49

The dependent variables used in the regressions are the number of transactions as well as dollar volume and average trade size, both in HK\$1000, measured during the 30-minute intraday interval. All of the dependent variables are log-transformed. All within-group dummy variable coefficients are restricted to total zero in order to avoid linear dependency among the independent variables. The *t*-statistics are based on the White heteroskedasticity consistent standard errors.

dollar volume, and average trade size measured during half-hour intervals. All of the dependent variables are log-transformed because of skewness in their distributions. The average number of transactions, dollar volume, and trade size are 2.36, 6.19, and 3.84, respectively. These figures are equivalent to 11 transactions and HK\$488,000 in volume during a typical half-hour interval, with an average trade size of HK\$47,000. The regression results suggest that trading volume and trade size increase with firm size.

The weekday dummies' coefficients do not exhibit any discernible patterns for any of the three trading activity measures. However, the coefficients of the intraday dummy variables show a clear U-shaped intraday pattern. The trading activities, measured by all three proxies, are concentrated at the beginning (10:00 to 10:30 AM) of the morning and at the end of the afternoon (3:30 to 3:55 PM) sessions.<sup>13</sup> The number of trades and dollar volume are smallest during the half-hour interval right before the lunch break.

The U-shaped intraday pattern in trading activity reported in Table 7 is generally consistent with the U-shaped spread and reverse U-shaped depth patterns reported in the earlier sections. If trading activity is positively related to informed trading, then increased informed trading around the market open and close will worsen the adverse selection problem for limit order traders, thus leading to a U-shaped spread and a reverse U-shaped depth pattern.

### *3.4. Relation between spread and depth*

It may be difficult to make inferences about liquidity on the basis of either spreads or depth alone. Lee et al. (1993) argue that the combination of wider (narrower) spreads and smaller (greater) depths is sufficient to infer a decrease (an increase) in liquidity. Although the empirical results reported in the previous sections suggest a negative relation between spread and depth, it is not clear whether the generally negative relation between spread and depth would hold, even if we controlled the pronounced intraday effects.

To determine the extent of the negative relation between spread and depth after controlling for the intraday patterns, we examine the correlation between them during each 30-minute interval of the trading day at the individual-firm level. If a stock's liquidity is lowest at the open and close of the trading day, we would expect to find higher negative correlations between spread and depth, at the open and the close than during the rest of the trading day.

We focus on the 33 Hang Seng Index (HSI) component stocks. HSI component stocks are the most actively traded stocks on the SEHK. They provide a reasonable representation of the market, since they account for more than 75% of market capitalization and 70% of total dollar volume. Limiting the analysis to the most actively traded stocks minimizes possible biases caused by thin trading.

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<sup>13</sup> Chan (1997) also reports similar findings in the trading volume pattern on the SEHK.

Table 8  
Correlation between spreads and depths

Time	10:00– 10:30 AM	10:30– 11:00 AM	11:00– 11:30 AM	11:30 AM– 12:00 PM	12:00– 12:30 PM	2:30– 3:00 PM	3:00– 3:30 PM	3:30– 3:55 PM	All
Mean	–0.135	–0.028	–0.051	–0.025	–0.050	–0.069	–0.004	–0.081	–0.123
S.D	0.242	0.251	0.234	0.197	0.215	0.308	0.211	0.148	0.213
Min.	–0.852	–0.314	–0.748	–0.371	–0.745	–0.841	–0.396	–0.232	–0.620
1st Q	–0.256	–0.215	–0.191	–0.141	–0.166	–0.212	–0.396	–0.192	–0.250
Med.	–0.141	–0.073	–0.052	–0.056	–0.079	–0.041	–0.144	–0.104	–0.140
3rd Q	0.005	0.048	0.070	0.079	0.093	0.140	–0.019	–0.032	–0.010
Max.	0.287	0.832	0.430	0.371	0.365	0.459	0.543	0.460	0.400
<i>p</i> -value (sign test)	0.013	0.089	0.019	0.027	0.060	0.089	0.016	0.004	0.005

The correlation between spreads and depths is computed for each stock and for each 30-minute trading interval of the day. Cross-sectional summary statistics are reported. The sample consists of the 33 Hang Seng Index component stocks.

Table 8 reports the summary statistics of correlations between spread and depth at the individual firm level for each half-hour interval of the day. The last column (“All”) of the table reports the summary statistics of correlations computed for each firm without controlling for the time of the day.

The mean and median correlations for all of the eight intraday intervals are negative, confirming the negative relation between spread and depth. The non-parametric sign test result indicates that the negative median correlations for the eight half-hour intervals are all statistically significant at the 10% level. The average and median of correlations for the entire day are  $-0.123$  and  $-0.140$ , respectively. Table 8 also shows that these negative correlations are strongest at the opening and closing half-hour intervals, suggesting that the negative relation between spread and depth is most pronounced during these periods.

#### 4. Conclusion

This study analyzes the behavior of the spread and depth, using information found in the *Trade Record* and the *Bid and Ask Record* of the 471 stocks traded on the SEHK between October 1996 and March 1997. We find that spreads are negatively associated with depths. Spreads exhibit U-shaped intraday and intraweek patterns, and depths display reverse U-shaped intraday and intraweek patterns. The negative relation between spread and depth is significant even after we control for the time-of-the-day effect.

The negative association between spread and depth on the SEHK implies that limit order traders actively manage both the price and quantity dimensions of liquidity by adjusting the spread and depth. The combination of a wider spread and smaller depth around the SEHK’s open and close is consistent with the trading strategy adopted by limit order traders. These traders attempt to minimize losses from trading with the informed when they face a severe adverse selection problem around these periods.

The general patterns of the spread and depth on the SEHK are similar to those observed on the NYSE. Most of the studies that investigate the market microstructure of the NYSE attribute the U-shaped intraday pattern of spreads to the optimal quoting behavior of specialists. However, the evidence presented in this paper suggests that the intraday pattern should not be solely attributed to specialists’ market-making activities because the SEHK does not operate with the market-maker system.

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