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# Short sales and speed of price adjustment: Evidence from the Hong Kong stock market 

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#### Abstract

We present empirical evidence that short sales contribute to market efficiency by increasing the speed of price adjustment to not only private/public firm-specific information but also market-wide information. Shortable stocks are characterized by weaker trade continuity and stronger quote reversals. They adjust faster to new information than non-shortable counterparts. These findings remain robust even in an "up" market condition in which short sales are not binding. The amount of information incorporated in each trade is also significantly higher for shortable than non-shortable stocks in both "up" and "down" market conditions. After controlling for firm size, trading volume, liquidity, price and option trading, short sales stand out as one of the significant factors that speed up the price adjustment.


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## 1. Introduction

A short sale is a trading strategy that capitalizes on anticipated declines in the price of a security. Shares are borrowed and sold in the open market and then bought back and returned at some point in the future. Short sellers profit if the share prices decline or incur losses if the prices rise. Both academicians and practitioners have long been interested in studying the benefits and costs of short sales. One of the major research focuses is the impact of short sales on price efficiency. In an efficient price discovery process, the price of a security should fully reflect all current and past information and should adjust to new information instantaneously (Fama, 1991). Short sales restrictions and prohibitions constrain investors from reacting to bad news but not good news, delaying the speed of price adjustment to negative information and causing an asymmetric price transmission process. Asymmetric price transmission refers to pricing phenomenon occurring when prices react

[^0]to negative information in a different manner than positive information. Asymmetric price transmission has two angles, asymmetric magnitude of price changes and asymmetric speed of price adjustment. The majority of past studies focus on the former angle, especially the relation between short sales and stock overvaluation (Miller, 1977; Figlewski, 1981; Danielsen and Sorescu, 2001; Jones and Lamont, 2002; Ofek and Richardson, 2003; Chang et al., 2007, among others).

This paper focuses on the latter angle, by measuring the speed of price adjustment to new information. We add at least four new contributions to the study of short sales: first, we examine the impact of short sales on the speed of price adjustment to both private/public firm-specific information and market-wide information. ${ }^{1}$ Second, we anatomize and contrast the price discovery processes of shortable and non-shortable stocks. We discover that shortable and non-shortable stocks differ in trade continuity, quote reversals, and incorporation of information in each trade. Third, we evaluate the speed of price adjustment both in "down" and "up"

[^1]market conditions. The role of short sales has not been studied in the up market condition because it was considered not binding. Fourth, we compare the impact of short sales on the speed of price adjustment to new information while firm-specific characters, such as trading volume, firm size, liquidity, the availability of options, price level, etc., are controlled.

Our analyses yield the following results. First, shortable stocks need fewer trades and less time to adjust to new information than non-shortable stocks. Second, when a stock is shortable, its trade continuity is weaker, quote reversal is stronger, and the amount of information incorporated from each trade is larger than a non-shortable counterpart. ${ }^{2}$ Third, short sales speed up the price adjustment to not only private/public firm-level information but also market-wide information. Fourth, all of the results are robust in both up and down market. Fifth, short sale remain significant in enhancing the speed of price adjustment after controlling for the firm size, liquidity, trading volume and optioned status are controlled.

The rest of the paper is organized as follows: Section 2 examines the current literature on short sales; Section 3 introduces the institutional background and data; Section 4 tests the first hypotheses on the speed of price adjustment to the private/public firm-specific information content of each trade; Section 5 tests the second hypothesis on the speed of price adjustment to market-wide information; Section 6 presents the results of various robustness checks. In particular, we examine whether short sales play any role in an up market situation in which short sales are not binding. We also examine what happens to the speed of price adjustment for those stocks that are removed from the D-list. We also compare the speed of price adjustment of optioned and non-optioned stocks. We then compare the significance of short sale with other firm-specific characters, on enhancing the speed of price adjustment. Section 7 concludes the paper.

## 2. Literature review

Diamond and Verrecchia ("DV" hereafter) (1987) predict that short sales prohibitions/restrictions lead to asymmetric price discovery processes, which hinder the speed of price adjustment to new information. Specifically, DV make four predictions: first, the dominant effect of short sales constraints is the reduction of the speed of price adjustment to private/public information, especially to bad news. Second, short sales constraints lead to a larger price adjustment on information announcement days and excess returns are more skewed to the left. Third, a period of inactive trade imparts a downward bias to excess returns because the previous transaction price is a measure of a security's value biased upward. Fourth, an unexpected increase in the announced short interest in a stock is bad news.

Most of the previous studies focus on testing DV (1987)'s second and third predictions. For example, Hong and Stein (2003) demonstrate how heterogeneous opinions can exacerbate market declines to make stock returns more negatively skewed if short sales are constrained. Bris et al. (2007) report that the lifting of short sales restrictions is associated with increased negative skewness in market returns. Driessen and Laeven (2007) demonstrate that global diversification benefits are not much affected when controlling for short sales constraints in developing countries. Reed (2003) finds that securities with short sales constraints have a larger price reaction when private information becomes public. The third prediction is closely related to Miller's (1977) hypothesis on overvaluation and short sales restrictions. Figlewski (1981), Danielsen and

[^2]Sorescu (2001), Jones and Lamont (2002), Ofek and Richardson (2003), Chang et al. (2007), and Diether et al. (2009a) all test DV's third prediction. For example, Chang et al. (2007) analyze the cumulative abnormal returns around the lifting and reinstating of short sales restrictions and find that individual stock returns exhibit higher volatility and less skewness when short sales are allowed. Diether et al. (2009a) find that short sellers target on overvalued stock and help correct the price by increasing short selling activities. Wu (2007) reports that the price of a stock with higher shorting volume tend to remain more closely with its fundamental value. Boehmer et al. (2008) observe that short sellers are generally well-informed and contribute to price efficiency. Daske et al. (2006) cast a doubt on the informed short seller hypothesis by indicating that short selling activities do not concentrate on firm-specific information. Kallio and Ziemba (2007) treat short selling constraints as one of frictions in arbitrage pricing conditions.

Beginning with Asquith and Meulbroek (1995), empirical evidence in support of DV's fourth prediction has been compiled in support of the bearish signal of short interest (Aitken et al., 1998; Desai et al., 2002; Ackert and Athanassakos, 2005; Asquith et al., 2005). Aitken et al. (1998) find that the market interprets short sales as bad news and responds quickly. Other studies focus on the effect of short sale constrains on the stock price volatility and liquidity. Charoenrook and Daouk (2005) find that when short sale is possible, aggregate stock return is less volatile and there is greater liquidity. Gao et al. (2006) find that allowing for short sales reduces transaction costs and is associated with the reduction of adverse selection component of the bid-ask spread. Asem (2009) demonstrates that buying winner stocks with increases in dividends and shorting loser stocks with decreases in dividends enhance momentum profits.

There are, however, only three studies that test DV's first prediction on the speed of price adjustment to new information but indirectly. The scarcity of empirical tests is largely attributed to the lack of transaction data and the difficulty of measuring the speed of price adjustment to new information. Diether et al. (2009b) examine the trading activities under the SEC pilot program in NYSE and Nasdaq. They find that the suspension of short sales constraints improves the symmetric price transmission process without significantly sacrificing volatility and liquidity. Fung and Draper (1999) demonstrate that relaxing short selling constraints reduces mispricing of index futures contracts. They conclude that reducing the restrictions on short sales speeds up the market adjustments and thereby provide indirect evidence that short sales enhance the speed of price adjustment. Bris et al. (2007) compare cross-autocorrelations between weekly lagged market returns and individual stock returns in 46 equity markets with and without short sales practiced and for dually listed stocks. They find a negative association between short sales restrictions and the diffusion of negative information into prices and show that the ability to short sell facilitates an efficient price discovery process. They did not directly measure the speed of price adjustment.

We measure the respective speed of price adjustment of shortable and non-shortable stocks. While so doing, the adjustment speed in reaction to not only private/public firm-specific information but also market-wide information is examined using high frequency transaction data. Furthermore, we directly examine the short sale effect on the adjustment speed in the both up and down market conditions. We adopt Hasbrouck's (1991) dynamic vector autoregressive (VAR) model to test the speed of price adjustment to information contained in each trade. We first examine the trade continuity and quote reversals, and then we compute the impulse response function in the number of trades and calendar time. In addition, we compute two speed measures from Jones and Lipson's (1999) partial adjustment model (PAM) and Chordia and Swamina-
than's (2000) logit transformation of betas from the Dimson beta regression to examine the speed of price adjustment to marketwide information. These approaches, though applied to different empirical settings, render two direct speed measures which can be used to directly test for the short sales effect on the speed of price adjustment.

Another limitation faced by previous studies is that virtually all stocks can be sold short in the US market, which makes it difficult to compare the speed difference between the same sets of stocks with and without short sales restrictions. Bris et al. (2007) avoid this difficulty by comparing stock price adjustments with and without short sales constraints in dual listing markets. We avoid the cross-border comparison by utilizing HKEx's unique institutional setting related to D-list stocks. Hence, one major advantage of this study is the investigation of the same set of stocks in a single market before and after they become shortable. Chang et al. (2007) and Gao et al. (2006) also use Hong Kong data, but their focuses are different than ours. Chang et al. (2007) examine DV's third hypothesis on overpricing issue while Gao et al. (2006) study the impact of short sales on market liquidity and volatility. In contrast, we focus on the speed of price adjustment to new information.

## 3. Institutional background and data description

### 3.1. Short sales in Hong Kong

Short sales were first introduced in January 1994 in HKEx. The HKEx allows only the stocks satisfying certain requirements to be sold short. The qualified stocks are listed on the D-list. Any stocks not on the D-list are prohibited from short sales. This restriction makes the HKEx unique, whereas almost all stocks can be sold short in the NYSE and the NASDAQ. ${ }^{3}$ Another unique feature of HKEX is the daily dissemination of short sale information, whereas short interest data are released only monthly in the US markets. These salient features of the HKEx provide an ideal setting to examine the short sales effect on the speed of price adjustment. ${ }^{4}$

By the end of 2004, a total of 1971 securities issued by 892 companies were listed on the HKEx main board with a market capitalization amounting to HK\$6629 billion (or US $\$ 850$ billion). The HKEx is a pure order-driven market without market makers. Trading operates through the third generation automatic order matching and execution system (AMS/3). Orders are automatically matched and executed based upon price and time priority. The securities borrowing and lending regulations require that a securities borrower maintain collateral no less than $105 \%$ of the market value of the securities borrowed. The up-tick rule requires that short sales should be made at prices not below the current ask price. The non-naked rule prohibits "naked" or "uncovered" short sale. ${ }^{5}$

The HKEx reviews the D-list on the quarterly basis to add and remove securities from the list. There are 229 stocks on the D-list in the last quarter of 2004. The selection criteria of the D-list stocks include: (i) all component stocks of market indices on which financial derivatives are written and traded in HKEx; (ii) underlying stocks of individual stock options and futures; (iii) stocks meet the minimum public flotation of $\mathrm{HK} \$ 1$ billion, the minimum market capitalization of HK\$1 billion, and the liquidity requirement of

[^3]Table 1
Changes in the designated list. The table reports the changes in the designated list (Dlist) from December 2001 to 2004. Stocks on the list are allowed to be sold short; stocks not on the list or removed from the list are not allowed to be sold short.

| Effective <br> date | No. of <br> additions | No. of <br> removals | No. of stocks on the D-list |
| :--- | :--- | :--- | :--- |
| $12 / 3 / 2001$ | 17 | 85 | 157 |
| $2 / 25 / 2002$ | 7 | 14 | 150 |
| $5 / 21 / 2002$ | 11 | 6 | 155 |
| $7 / 17 / 2002$ | 24 | 5 | 174 |
| $11 / 21 / 2002$ | 6 | 15 | 165 |
| $1 / 21 / 2003$ | 5 | 7 | 163 |
| $5 / 19 / 2003$ | 18 | 7 | 174 |
| $7 / 21 / 2003$ | 1 | 16 | 159 |
| $11 / 3 / 2003$ | 36 | 5 | 189 |
| $1 / 6 / 2004$ | 1 | 0 | 190 |
| $2 / 10 / 2004$ | 29 | 3 | 217 |
| $4 / 7 / 2004$ | 26 | 4 | 240 |
| $7 / 1 / 2004$ | 1 | 0 | 241 |
| $7 / 9 / 2004$ | 1 | 0 | 242 |
| $8 / 2 / 2004$ | 8 | 21 | 229 |
| $11 / 8 / 2004$ | 9 | 11 | 228 |

at least $40 \%$ turnover ratio. ${ }^{6}$ The stocks that meet any one or more of the criteria for at least 3 months are included in the D-list.

### 3.2. Data description

The study period is from December 2001 to 2004, the D-list has been revised 16 times during the study period. The changes in the D-list since November 2001 are summarized in Table 1, illustrating the records of additions and removals from the D-list.

We investigate the speed of price adjustment to new information for the stocks 3 months before and after they join the D-list. Our sample selection has the following advantages. First and most important, according to the HKEx selection criteria, stocks on the D-list must have met one of the criteria for 3-12 months of trading period before they are added on the D-list. This means that any difference in the speed adjustment between three months before and after the stock becomes shortable should be mainly attributed to the change in short sales prohibitions rather than the changes in firm characteristics, including, in particular, the improvement of liquidity. This settings and selection rule avoid the confounding effect caused by the changes in firm fundamentals. Second, the inclusion decision in the D-list is made by the HKEx not by the firm, which allows us to avoid the self-selection bias. Third, the use of HKEx data mitigates the clustering effect of an event analysis because the effective days of sample stocks becoming shortable are distributed across the entire 3 -year study period. Each stock has different event day. Hence, this external selection rule adopted by HKEx allows us to examine the pure effect of changes in short sales constraints on the speed of price adjustment.

We exclude those stocks traded less than 600 days during the study period of 763 trading days. The total number of sample stocks remains at 816 . We have 182 stocks that have been added to the D -list during the study period with trading data starting from 3 months before to 3 months after the D-list effective days. To examine the speed of price adjustment in the absence of the options effect, 35 optioned stocks are excluded in the initial sample. In the robustness test, however, we bring them back in to investigate the speed of price adjustment with and without financial derivatives written. The quarterly D-list announcements, daily short interest data, transaction data, and the bid-and-ask price data

[^4]Table 2
Summary statistics of D-list stocks. Panel A reports the summary statistics of D-list stocks during the study period, December 2001-2004. Market capitalization is the average value of equities in millions of Hong Kong dollars; outstanding share is the average outstanding shares in millions of shares; the price/book is the average price-to-book ratio; short interest is the average daily short interest in millions of shares; daily turnover is the average daily trading volume in millions of shares; illiquidity ratio is calculated following Amihud (2002), which is defined as the average daily absolute return divided by the dollar volume. The Amihud ratio is characterized by "the higher the ratio, the less the liquidity"; daily short ratio is the percentage of daily trading volume that is sold short. Panel B reports the distribution of the percentage of shorted shares. Each variable is calculated for each stock in the sample period, then compute the mean across stocks.

| No. of stocks | Whole market$816$ | Sample stocks |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  |  | Non-shortable 182 | Shortable $182$ | $P$-Value of equality-test |
| Panel A: summary statistics |  |  |  |  |
| Average market capitalization (HK\$ million) | 5746 | 5230 | 5213 | 0.88 |
| Outstanding share (millions of shares) | 1273 | 1324 | 1324 | 0.62 |
| Price (HK\$) | 4.97 | 10.92 | 10.77 | 0.76 |
| Price/book | 1.86 | 1.61 | 1.58 | 0.35 |
| Daily turnover (millions of shares) | 12.43 | 12.27 | 12.53 | 0.18 |
| Average illiquidity ratio | 0.46 | 0.41 | 0.39 | 0.16 |
| Panel B: daily short selling and the frequency distribution of shortable stocks |  |  |  |  |
| Daily short interest (millions of shares) |  |  |  | 0.61 |
| Daily short ratio (\%) |  |  |  | 8.67 |
| Statistics distribution of daily short ratio |  |  |  |  |
| Maximum value |  |  |  | 43.68 |
| 50\% (median) |  |  |  | 6.87 |
| Minimum value |  |  |  | 0.05 |
| Mean |  |  |  | 8.67 |
| $t$-Value |  |  |  | 9.51 |

have been supplied by the HKEx. The stocks' financial data, which include market capitalization, share outstanding and price-to-book ratio, are obtained from Bloomberg. Table 2 presents summary statistics of the sample stocks.

Panel A of Table 2 presents the summary statistics of the sample stocks depending on when they are shortable and non-shortable. The average market capitalization, price-to-book ratio, turnover and illiquidity ratio of the 816 stocks is $\mathrm{HK} \$ 5.75$ billion, 1.86 , 12.43 millions and 0.46 , respectively. For 182 sample stocks, when shortable and non-shortable, the market capitalizations are HK $\$ 5.21$ billion and HK $\$ 5.23$ billion, respectively; the price-tobook ratios are 1.61 and 1.58 , respectively; the daily turnover ratios are 12.27 million and 12.53 millions; the illiquidity ratios are 0.41 and 0.39 , respectively. The equality-of-mean tests indicate that these figures are not different, confirming that firm characteristics of the sample stocks are about the same before and after they join the D-list. Hence, any change on the speed of price adjustment should be attributed to the relaxation of short sale restriction rather than the change in firm characteristics. Panel B summarizes the daily short selling activity for shortable stocks and the frequency distribution of the short ratio. The average daily short interest is 0.6 million shares or about $5 \%$ of the average daily trading volume. The average ratio of short interest to total trading volume is $8.67 \%$. This indicates that when stocks are shortable, approximately 1 out of every 12 trades is a short sale.

## 4. Speed of price adjustment to private/public firm-specific information

In this section we examine the speed of price adjustment to firm-specific information, and contrast the speed before and after stocks become shortable. We hypothesize that:

Hypothesis 1. The speed of price adjustment to new private/public firm-specific information contained in each trade is faster for shortable than non-shortable stocks.

Hasbrouck's (1991) dynamic VAR and Jones and Lipson's (1999) PAM are used to test this hypothesis. Hasbrouck (1991) suggests that trades convey information and cause a persistent impact on the security price. Using a VAR model, he captures the interactions
of security trades and quote revisions and concludes that a trade's information effect may be measured as the ultimate price impact of the trade innovations. He further suggests that the information contained in each trade includes both private and public information, and the VAR model provides a resolution between private information (the trade innovation) and public information (the quote revision innovation). We estimate both Hasbrouck's VAR model and the cumulative impulse response to contrast the price discovery processes of shortable and non-shortable stocks. Jones and Lipson's (1999) PAM is then employed to measure the speed of quoted price adjustment.

### 4.1. Dynamic unrestricted VAR

Hasbrouck (1991) suggests that the information impact of a trade be defined as the ultimate impact on the stock price (or quote) resulting from the unexpected component of the trade, i.e., the persistent price impact of the trade innovation. Specifically, we estimate the following VAR model:
$r_{t}=\sum_{i=1}^{5} a_{i} r_{t-i}+\sum_{i=0}^{5} b_{i} Q_{t-i}+v_{1, t}$
$Q_{t}=\sum_{i=1}^{5} c_{i} r_{t-i}+\sum_{i=1}^{5} d_{i} Q_{t-i}+v_{2, t}$
where $r_{t}=m_{t}-m_{t-1}$ is the log quote-midpoint change due to transaction $t$ and $m_{t}$ is the log midpoint of the quote when a transaction occurs at time $t$. $Q_{t}$ is the buy-sell indicator equal to $[1,0,-1]$ if the trade occurs [above, at, below] $m_{t-1}$. The coefficients $a_{i}$ indicate the autocorrelation in the quote revision, and $d_{i}$ indicate the autocorrelation in trade. The coefficient $b_{0}$ captures contemporaneous correlation between order flow and quote-midpoint return. ${ }^{7}$ The coefficients $b_{i}$ capture the quote adjustment subsequent to each trade, and coefficients $c_{i}$ indicate the Granger causality running from quote revision to trades. The model is estimated using five lags. The number of lags is determined by examining the cross-autocorrelations, which indicate that the coefficients of higher lags are not

[^5]Table 3
Estimates of the dynamic unrestricted VAR and the cumulative impulse response in the number of trades. This table reports the results of the following dynamic bivariate VAR model:
$r_{t}=\sum_{i=1}^{5} a_{i} r_{t-i}+\sum_{i=0}^{5} b_{i} Q_{t-i}+v_{1, t}$
$Q_{t}=\sum_{i=1}^{5} c_{i} r_{t}-i+\sum_{i=1}^{5} d_{i} Q_{t-i}+v_{2, t}$
where $r_{t}=m_{t}-m_{t-1}$ is the log quote-midpoint change in dollars due to transaction $t, m_{t}$ is the log midpoint of the quote when a transaction occurs at time $t$, $Q_{t}$ is the buy-sell indicator equal to [ $1,0,-1$ ] if the trade occurs [above, at, below] $m_{t-1}$. The first and last 15 min of trades for each trading day are removed to avoid the effect of overnight returns and abnormal trading activity during the morning opening and afternoon closing periods. The model is estimated daily for the 3-month period before and after a stock joins the D-list. Panel A reports the results for the VAR regression. The $P$-values are reported in the parentheses. The $P$-value in the last row under each coefficient is for the equality-test between the periods before and after the stock joins the D-list. Panel B reports the cumulative quote-midpoint return $m_{t+j-1}-m_{t-1}$ in response to a unit shock in trade.

|  | Shortable stocks |  | Non-shortable stocks |  |  |  | Shortable stocks |  | Non-shortable stocks |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Coeff. | $P$-Value | Coeff. | $P$-Value |  |  | Coeff. | $P$-Value | Coeff. | $P$-Value |
| Panel A: estimation results of the VAR regression |  |  |  |  |  |  |  |  |  |  |
| a1 | -0.17 | (0.0001) | -0.06 | (0.0001) | c1 |  | -0.16 | (0.0001) | -0.15 | (0.0001) |
| a3 | -0.05 | (0.0001) | -0.01 | (0.0001) | c3 |  | -0.02 | (0.0001) | -0.02 | (0.0001) |
| a5 | -0.02 | (0.0538) | 0.02 | (0.0042) | c5 |  | 0.00 | (0.2537) | 0.00 | (0.2126) |
| $P$-Value of equality-test | (0.003) |  |  |  |  | ity-test | (0.871) |  |  |  |
| b0 | 0.40 | (<0.0001) | 0.32 | (<0.0001) |  |  |  |  |  |  |
| b1 | 0.37 | (0.0001) | 0.29 | (0.0001) | d1 |  | 0.28 | (0.0001) | 0.43 | (0.0001) |
| b3 | 0.05 | (0.0001) | 0.04 | (0.0001) | d3 |  | 0.05 | (0.0001) | 0.16 | (0.0001) |
| b5 | 0.00 | (0.0791) | 0.02 | (0.1101) | d5 |  | 0.00 | (0.0001) | 0.06 | (0.0001) |
| $P$-Value of equality-test | (0.063) |  |  |  |  | ality-test | (0.031) |  |  |  |
| $\bar{R}^{2}$ | 0.18 |  | 0.16 |  | $\bar{R}^{2}$ |  | 0.24 |  | 0.25 |  |
| Panel B: cumulative impulse response of quoted price to a unit shock in $Q_{t}$ |  |  |  |  |  |  |  |  |  |  |
| No. of trades | Shortable stocks |  |  |  |  | Non-shortable stocks |  |  |  |  |
|  | Quote responses |  | Standard dev. |  | (\%) | Quote responses |  | Standard dev. |  | (\%) |
| 1 | 0.29 |  | 0.001 |  | 45 | 0.15 |  | 0.001 |  | 23 |
| 2 | 0.40 |  | 0.001 |  | 62 | 0.24 |  | 0.001 |  | 36 |
| 3 | 0.46 |  | 0.001 |  | 70 | 0.31 |  | 0.001 |  | 47 |
| 5 | 0.54 |  | 0.001 |  | 83 | 0.42 |  | 0.001 |  | 64 |
| 10 | 0.64 |  | 0.002 |  | 98 | 0.57 |  | 0.001 |  | 86 |
| 12 | 0.65 |  | 0.003 |  | 100 | 0.59 |  | 0.002 |  | 90 |
| 30 | 0.65 |  | 0.006 |  | 100 | 0.65 |  | 0.009 |  | 99 |

significant. All regressions are estimated with the White heteroscedasticity correction for standard errors. The model is estimated daily for the 3 -month period before and after a stock joins the D-list. The first and last 15 min trades of each trading day are removed to avoid the effect of overnight returns and abnormal trading activity during the morning opening and afternoon closing periods. Table 3 Panel A presents the results of VAR.

The estimation of $b_{0}$ is 32 and 40 basis points before and after the stocks join the D-list, which implies that on average the quote-midpoint rises by $\mathrm{HK} \$ 0.04$ ( $\mathrm{HK} \$ 0.03$ ) immediately after a purchase order when a stock is shortable (non-shortable). The coefficients at longer lags $b_{i}$ are generally positive but decreasing in magnitude. The positive autocorrelation in the trades reflected by the coefficients $\sum_{i=1}^{5} d_{i}$ suggests trading continuity, which implies that purchases tend to follow purchases and sales are more likely to follow sales. The negative autocorrelation in the quote adjustment reflected by the coefficients $\sum_{i=1}^{5} a_{i}$ suggests quote reversals. Hasbrouck and Ho (1987) and Hasbrouck $(1988,1991)$ find strong positive autocorrelations in trades and conclude that the absence in trade reversals is consistent with inventory control. Hasbrouck (1991) conclude that positive autocorrelations in trades and negative autocorrelations in quote revisions are consistent with lagged adjustment to new information.

The differences between the shortable and non-shortable stocks are reflected in quote reversals and trade continuity. The magnitude of $\sum_{i=1}^{5} d_{i}$ for shortable stocks is smaller than that for non-shortable counterparts, and the difference is significant at the $5 \%$ level, which implies that shortable stocks have significantly weaker trade conti-
nuity than non-shortable stocks. The estimated $\sum_{i=1}^{5} c_{i}$ are similar in both period, while those of $\sum_{i=1}^{5} a_{i}$ are more negative for shortable stocks than non-shortable stocks; and the difference is significant at the $1 \%$ level, which implies that quote reversal is much stronger when the stock is shortable than non-shortable. To further examine the changes in the trade continuity and quote reversals, we plot the daily trade continuity and trade reversals in Fig. 1 and the daily return, volume and short interest in Fig. 2 over the 11-day period before and after the event day when stocks become shortable. ${ }^{8}$

Fig. 1 shows that the trade continuity drops significantly on day 0 when stocks become shortable and subsequently remains in the lower level than when the stocks are non-shortable. The quote reversals also become significantly more negative for shortable than non-shortable stocks. Fig. 2 shows that the daily return declines dramatically on the event day and remains in the negative range 5 days after stock become shortable. This reflects the downward adjustment of overvalued stocks when they become shortable. ${ }^{9}$ Both daily trading volume and short interest are the highest on days 0 and 1, but on average volume does not change significantly before and after the event day.

Stronger trade continuity and weaker quote reversals imply slower speed of price adjustment to new information. Hasbrouck

[^6]

Fig. 1. Trade continuity and quote reversals around the D-list effective day.


Fig. 2. Daily return, volume and short interest around the D-list effective day.
(1991) finds that strong trade continuity is consistent with lagged adjustment to new information. Hence, weaker trade continuity leads to faster adjustment to new information. Madhavan et al. (1997) find that stronger trade continuity leads to weaker quote reversal, the larger the information asymmetry component, the stronger the effect. The underlying intuition is that, the greater the autocorrelation in order flow, the less the revision in beliefs, and the slower the price adjust to new information. If trade is positively correlated, successive transactions at the bid or the ask are more likely to continue than reverse and this will delay the price adjustment. Therefore, stronger trade continuity and weaker quote reversals lead to a slower speed of price adjustment to new information. In contrast, weaker trade continuity and stronger quote reversals lead to a faster speed of price adjustment. Table 3 indicates that short sales reduce the trade continuity and increase the quote reversals, thus enhance the stock price adjustment process.

To further investigate whether weaker trade continuity and stronger quote reversal lead to a faster speed of adjustment, the


Fig. 3. Cumulative impulse response in the number of trades.
cumulative quote-midpoint response to a unit innovation in trade is examined. The results are detailed in Panel B of Table 3 and are displayed in Fig. 3.

The results show that the eventual price impact following a unit shock to $Q_{t}$ is 0.65 for shortable and 0.66 for non-shortable stocks. The immediate quote adjustment is $45 \%$ of the total adjustment for shortable stocks, while it is only $23 \%$ for non-shortable stocks. The second quote adjustment reaches $62 \%$ of total adjustment for shortable stocks and only $36 \%$ for non-shortable stocks. It takes about eight trades to accomplish $95 \%$ of the total price adjustment for shortable stocks and more than 20 trades to accomplish the same level of price adjustment for non-shortable stocks. The impulse responses are also measured in calendar time. The results are presented in Table 4 and displayed in Fig. 4.

The eventual quote adjustment measured in calendar time is approximately 0.35 for shortable stocks and 0.36 for non-shortable stocks. Within 1 min of a trade innovation, quotes adjust about $59 \%$ of the total quote adjustment for shortable stocks and only $35 \%$ for non-shortable stocks. 15 min after the first trade innovation, shortable stocks have accomplished $90 \%$ of the total adjustment, while non-shortable stocks have accomplished only $74 \%$. Overall, the impulse response measured in calendar time reconfirms the results from the impulse response measured in trades. The overall results from the VAR model and its impulse response function provide strong evidence that stocks in the D-list need significantly fewer trades and shorter time to adjust to new information than when they are not in the D-list.

### 4.2. Partial adjustment model

Jones and Lipson's (1999) PAM is closely related to the Amihud and Mendelson (1987) and Damodaran (1993) models. The Jones and Lipson model has one major appeal to our analyses in this section. It is specifically designed for high frequency data in testing the speed of price adjustment. Another appeal is that the model captures the speed of quote adjustment and the information contained in each trade as two simple scalar quantities, which can be readily utilized to examine the impact of firm characteristics on the speed of price adjustment. This will be illustrated in Section 6.

In the Jones and Lipson (1999) model framework, we estimate the following regression:
$r_{i, t}=k+\sum_{j=0}^{4} \gamma \alpha(1-\gamma)^{j}\left[Q_{i, t-j}-E_{t-j-1}\left(Q_{i, t-j}\right)\right]+v_{i t}$
where $r_{i, t}=m_{i, t}-m_{i, t-1}$ is the log quote-midpoint change due to transaction $t$ for stock $i$, and $E\left[Q_{t}\right]$ is determined using a pooled AR (5) model with five lags of quote returns and signed trades. Other variables are defined as in Eq. (1). The model is fitted using the GMM and the Newey-West standard errors with five lags are computed. ${ }^{10}$ There are two parameters of interest in the model: (i) the speed of adjustment parameter $\gamma$; and (ii) the information parameter $\alpha$. Underreaction is associated with $\gamma<1$, overreaction is associated with $\gamma>1$, and $\gamma=1$ implies that the quote-midpoint adjusts fully to new information. A higher $\alpha$ implies more information is incorporated into each trade. The estimation results are summarized in Table 5.

The speed measure $\gamma$ is 0.66 for shortable stocks and 0.39 for non-shortable stocks with the difference significant at the $5 \%$ level. The results imply that $66 \%$ of the price impact of a trade is realized in each subsequent transaction for shortable stocks, while only $39 \%$ is realized for non-shortable stocks. The magnitude of the information parameter $\alpha$ is 4.29 when stocks are shortable and 0.61 when

[^7]Table 4
Cumulative impulse response in calendar time. This table measures the cumulative impulse responses in calendar time of the quoted price to a unit shock in trade by calendar time for stocks three moths before and after joining the D-list. At each time horizon, we report the slope coefficient in a pooled regression of the cumulative quote-midpoint return $m_{t+\tau}-m_{t-1}$ on the trade innovation $Q_{t}-E_{t-1}\left(Q_{t}\right)$, where $E_{t-1}\left(Q_{t}\right)$ is calculated using the dynamic unrestricted VAR in Table 3 with five lags of quote-midpoint returns and signed trades.

| Minutes | Shortable stocks |  |  | Non-shortable stocks |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Quote responses | Standard dev. | (\%) | Quote responses | Standard dev. | (\%) |
| 1 | 0.20 | 0.001 | 59 | 0.12 | 0.001 | 35 |
| 3 | 0.26 | 0.001 | 76 | 0.18 | 0.001 | 50 |
| 5 | 0.28 | 0.001 | 82 | 0.22 | 0.001 | 61 |
| 10 | 0.30 | 0.001 | 87 | 0.24 | 0.001 | 68 |
| 20 | 0.32 | 0.001 | 92 | 0.29 | 0.001 | 82 |
| 30 | 0.33 | 0.001 | 95 | 0.31 | 0.001 | 88 |
| 60 | 0.34 | 0.001 | 98 | 0.33 | 0.001 | 94 |
| 120 | 0.35 | 0.001 | 100 | 0.36 | 0.001 | 100 |



Fig. 4. Cumulative impulse response in calendar time.
they are non-shortable, respectively, with the difference significant at the $1 \%$ level. This suggests that stock prices incorporate significantly smaller amount of information if short sales are prohibited. The results of the PAM indicate that when a stock is shortable, it exhibits a faster speed of price adjustment to information and its trades incorporate more information than when it is non-shortable. These findings are consistent with those of the VAR model and strongly support Hypothesis 1.

## 5. Speed of price adjustment to market-wide information

DV (1987) predict that if a stock is prohibited from short selling, its price adjusts more slowly to new negative private information. Less explored in the literature is the short sale effect on market-wide information. In this section, we extend DV's model to specifically measure the speed of price adjustment to market-wide information of shortable and non-shortable stocks.
Hypothesis 2. The speed of price adjustment to market-wide information is faster for shortable stocks than non-shortable stocks.

Chordia and Swaminathan (2000) introduce a direct speed measure based on the transformation of the Dimson (1979) beta regression. They find that high-volume stocks respond faster to market-wide information than low-volume stocks. We use the same approach to test the speed of price adjustment to marketwide information for shortable and non-shortable stocks.

### 5.1. Dimson beta regression and the delay measure

The Dimson beta regression is estimated for individual stocks using ${ }^{11}$ :

[^8]$r_{i, t}=\alpha_{0}+\sum_{k=1}^{K} \beta_{i, k} r_{m, t-k}+\mu_{i, t}^{k}$
where $r_{i}$ is the 15 min return of stock $i, r_{m}$ is the 15 min market return; $\beta_{0}$ is the contemporaneous adjustment of market return, and $\sum_{k=1}^{K} \beta_{i, k}$ is the lagged adjustment to market return in time 0 . The Hang Seng Index is used as a proxy for the market portfolio, capturing the release of market-wide information. ${ }^{12}$ The regression is estimated using the GMM and the White heteroskedasticity correction to control for heteroskedasticity and auto-correlation. The GMM is also used to control for the possible cross-sectional autocorrelation of the estimates. The model is estimated using five lags. The number of lags is determined by examining the cross-autocorrelation, which indicates that the coefficients of lags are not significant.

In Eq. (3), if a shortable stock adjusts faster to contemporaneous market-wide information, its $\beta_{i, 0}$ should be greater than that of a non-shortable stock. Similarly, if a non-shortable stock adjusts slower to contemporaneous information, it should be more sensitive to ex-post market information (lagged $r_{m}$ ), which implies that $\sum_{k=1}^{K} \beta_{i, k}$ should be larger for a non-shortable than a shortable stock. Chordia and Swaminathan (2000) introduce a speed measure as shown in Eq. (4), it is the logit transformation of betas from Eq. (3)
$\operatorname{DELAY}_{i}=1 /\left(1+e^{-x}\right)$
where $x=\sum_{k=1}^{5} \beta_{i, k} / \beta_{i, 0}$. The value of DELAY is restricted between zero and one. A value closer to zero indicates a less delay in adjustment and a value closer to one implies a greater delay. Stocks with higher (lower) DELAY are the ones with slower (faster) speed of adjustment.

Table 6 reports the results of the Dimson beta regressions and the DELAY measure. The contemporaneous betas of both groups are significantly positive. The contemporaneous adjustment is 0.81 for shortable stocks and only 0.52 for non-shortable stocks. The two betas are significantly different in magnitude at the $5 \%$ level, which implies that shortable stocks respond faster and more fully to current market-wide information than non-shortable stocks. The sum of the lagged beta is 0.07 for shortable stocks and 0.19 for non-shortable stocks, which indicates that non-shortable stocks respond much more to lagged market information than their shortable counterparts. Furthermore, the speed measure, DELAY, is 0.47 for shortable stocks and 0.60 for non-shortable stocks. This indicates that shortable stocks have less delay on price adjustment to the market-wide information than non-shortable stocks. These findings extend the DV model and provide evidence showing that short sales not only enhance the speed of price

[^9]Table 5
Partial price adjustment model. This table contains the GMM estimations of the partial price adjustment model:
$r_{i, t}=k+\sum_{j=0}^{4} \gamma \alpha(1-\gamma)^{j}\left[Q_{i, t-j}-E_{t-j-1}\left(Q_{i, t-j}\right)\right]+v_{i t}$
where $r_{i, t}=m_{i, t}-m_{i, t-1}$ is the $\log$ quote-midpoint return prevailing when transaction $t$ in security $i$ occurs, and $Q_{t}$ is the associated buy-sell indicator equal to [1, $\left.0,-1\right]$ if the trade occurs [above, at, below] $m_{i, t-1} . E_{t-1}\left(Q_{t}\right)$ is determined using a pooled $\operatorname{AR}(5)$ model. $\gamma$ is the speed of adjustment parameter, where underreaction is associated with $\gamma<1$, overreaction is associated with $\gamma>1$, and $\gamma=1$ implies quote-midpoints adjust fully to new information; $\alpha$ is the information parameter with higher $\alpha$ implying more information incorporated in each trade. The model is estimated for stocks three months before and after they join the D-list. The pooled sample includes intraday trades and bid-ask record for the two 3 -month periods. Newey-West standard errors are estimated, and GMM is used to control for cross-sectional auto-correlation. The $P$-value in the parentheses tests the significance of the coefficients. The $P$-value in the last row test the equality of the parameters estimated between the periods before and after the stock joining the D-list.

|  | $\gamma$ (speed measure) |  | $\alpha$ (information level) | $\bar{R}^{2}$ |
| :--- | :--- | :--- | :--- | :--- |
| Shortable stocks | 0.66 | $(0.02)$ | 4.29 | $(0.01)$ |
| Non-shortable stocks | 0.39 | $(0.05)$ | 0.32 |  |
| $P$-Value of equality-test | $(0.02)$ |  | $(0.01)$ | 0.30 |

adjustment to firm-specific private and public information but also market-wide information.

## 6. Robustness tests

### 6.1. Do short sales matter on up market days?

DV (1987) suggest that short sales prohibitions/restrictions reduce informational efficiency with respect to both bad and good news. Few studies, however, have investigated what happens in an up market condition in which short sales constraints are not binding. It remains an empirical issue whether short sales matter on up market days which may be regarded as a consequence of arrival of good news. Furthermore, no past studies measure the speed differences between shortable and non-shortable stocks in down and up market conditions.

Specifically, we address the following two questions: (i) do stocks on the D-list exhibit faster speed on up market days? (ii) What is the speed difference of shortable and non-shortable stocks in up and down market conditions? To answer these questions we conduct two sets of empirical tests depending on how we define up and down market days. In the first test, we define the up (down) market day as a day with positive (negative) market index return. A total of 763 trading days is divided into 392 up market days and 371 down market days. In the second test, we divide the trading days for each stock to positive return days and negative return days. A positive (negative) return day is a trading day with positive (negative) open-to-close return. For each stock, we run the VAR and cumulative impulse response, the PAM, and the Dimson beta regressions in the two sets of trading days before and after it becomes shortable, respectively.

The VAR and impulse response results are summarized in Table 7 and Figs. 5-8. The most striking result is that short sales enhance the speed of price adjustment even on up market days and daily return up days. For market index indicator, on up (down) market days, shortable stocks attain $41 \%$ (49\%) of the total price adjustment after the first trade and accomplish $95 \%$ (95\%) of the total price adjustment in 10 trades, while non-shortable stocks attain only $32 \%$ ( $31 \%$ ) of the total price adjustment after the first trade and only complete $93 \%$ ( $80 \%$ ) of price adjustment after 10 trades. The speed differences between shortable and non-shortable stocks are significant in both up and down market days. Figs. 5 and 6 illustrate the impulse response functions in market index indicators. For daily return indicator, the results are consistent but more striking. On daily return up (down) days, shortable stocks attain $44 \%$ (30\%) of the total price adjustment after the first trade and accomplish $92 \%$ ( $93 \%$ ) of the total price adjustment in 10 trades, while
non-shortable stocks attain only $31 \%$ (20\%) of the total price adjustment after the first trade and only complete $74 \%$ ( $34 \%$ ) of price adjustment after 10 trades. After 30 trades, non-shortable stocks only accomplished $84 \%$ of the total adjustment. Figs. 7 and 8 show the impulse response function in daily return indicators, and it indicates that for daily return down days, non-shortable stocks initially adjust slowly to new information, but eventually tend to over-adjust in the end. The results for impulse response in calendar times are reported in Table 7 Panel B and consistent with Panel A's findings.

The PAM and Delay measure are presented in Table 8. The results are robust on both up and down market days. On up (down) market days, the speed measure $\gamma$ is 0.49 (1.02) for shortable stocks and 0.42 ( 0.79 ) for non-shortable stocks. On up (down) market days, the information parameter $\alpha$ is 8.62 (4.73) for shortable stocks and 3.76 ( 0.50 ) for non-shortable stocks. The results indicate that shortable stocks incorporate more than twice as much information in one transaction than non-shortable stocks on up market days, whereas shortable stocks incorporate almost eight times of information in one transaction than non-shortable stocks on down

## Table 6

Dimson beta regressions. The following regression is estimated using intraday 15 min returns from December 2001 to 2004:
$r_{i, t}=\alpha_{0}+\sum_{k=1}^{K} \beta_{i, k} r_{m, t-k}+\mu_{i, t}$
where $r_{o, t}$ is stock return at time $t$ and $r_{m, t-k}$ refers to intraday 15 min market return. The Hang Seng Index is used as the market index. $\sum_{K=1}^{K} \beta_{i, K}$ refers to the sum of lagged betas, $b_{0,0}$ refers to the contemporaneous beta. The regression is estimated for individual stocks using GMM and all statistics are computed based on White heteroskedasticity corrected standard errors. GMM is also used to control for cross-sectional auto-correlation. The significance levels for the Wald test statistics are based on standard $\chi^{2}$ distribution. DELAY is the speed of adjustment measure, defined as DELAY $=1 /\left(1+e^{-x}\right)$
where $x=\sum_{k=1}^{5} \beta_{j, i, k} / \beta_{j, i .0}$. DELAY is restricted between zero and one. Values closer to zero imply a faster speed of adjustment and values closer to one imply a slower speed of adjustment. The model is estimated for stocks before and after they join the D-list. $P$-Values in the parentheses indicate the significance of the coefficients, and $P$-value in the last column tests the equality of estimated coefficients between the periods before and after the stock joins the D-list.

|  | Shortable stocks | Non-shortable <br> stocks | $P$-Value of equality-test |
| :--- | :--- | :--- | :--- |
| $b_{\mathrm{i}, 0}$ | 0.81 | 0.52 |  |
|  | $(<0.0001)$ | $(<0.0001)$ | $(-0.03)$ |
| $\sum_{k=1}^{5} \beta_{i, k}$ | 0.07 | 0.19 | $(-0.06)$ |
| DELAY | $(<0.0001)$ | $(<0.0001)$ | $(-0.02)$ |
|  | 0.47 | 0.60 |  |
| $\bar{R}^{2}$ | $(<0.0001)$ | $(<0.0001)$ |  |

Table 7



 An "up" ("down") day is a day with a positive (negative) daily stock return. Panel A reports the impulse response by the number of trades and Panel B reports the impulse response in calendar time (in min).

|  | Market index return-based classification |  |  |  |  |  | Individual stock return-based classification |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Up market |  |  | Down market |  |  | Up days |  |  | Down days |  |  |
| Panel A: cumulative impulse response (by transactions) |  |  |  |  |  |  |  |  |  |  |  |  |
| Shortable stocks |  |  |  |  |  |  |  |  |  |  |  |  |
| No. of trade | Quoted response | Std. | \% | Quoted response | Std. | \% | Quoted response | Std. | \% | Quoted response | Std. | \% |
| 1 trade | 0.34 | 0.01 | 41 | 0.36 | 0.01 | 49 | 0.29 | 0.00 | 44 | 0.24 | 0.01 | 30 |
| 3 trades | 0.53 | 0.02 | 65 | 0.50 | 0.02 | 65 | 0.41 | 0.01 | 61 | 0.50 | 0.01 | 62 |
| 5 trades | 0.66 | 0.03 | 81 | 0.60 | 0.03 | 77 | 0.49 | 0.01 | 73 | 0.61 | 0.01 | 76 |
| 10 trades | 0.78 | 0.05 | 95 | 0.74 | 0.07 | 95 | 0.61 | 0.02 | 92 | 0.75 | 0.03 | 93 |
| 20 trades | 0.81 | 0.10 | 100 | 0.77 | 0.12 | 100 | 0.66 | 0.04 | 99 | 0.80 | 0.05 | 99 |
| 30 trades | 0.81 | 0.11 | 100 | 0.78 | 0.13 | 100 | 0.67 | 0.04 | 100 | 0.81 | 0.06 | 100 |
| Non-shortable stocks |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 trade | 0.22 | 0.01 | 32 | 0.23 | 0.01 | 31 | 0.21 | 0.00 | 31 | 0.16 | 0.00 | 20 |
| 3 trades | 0.42 | 0.02 | 60 | 0.36 | 0.02 | 50 | 0.30 | 0.00 | 46 | 0.19 | 0.01 | 23 |
| 5 trades | 0.53 | 0.02 | 76 | 0.44 | 0.02 | 61 | 0.36 | 0.01 | 55 | 0.22 | 0.01 | 26 |
| 10 trades | 0.64 | 0.05 | 93 | 0.58 | 0.05 | 80 | 0.49 | 0.01 | 74 | 0.28 | 0.02 | 34 |
| 20 trades | 0.68 | 0.10 | 98 | 0.70 | 0.10 | 97 | 0.63 | 0.03 | 97 | 0.45 | 0.04 | 55 |
| 30 trades | 0.69 | 0.11 | 100 | 0.72 | 0.11 | 100 | 0.65 | 0.04 | 100 | 0.68 | 0.05 | 84 |
| Panel B: cumulative impulse response (by calendar time) |  |  |  |  |  |  |  |  |  |  |  |  |
| Shortable stocks |  |  |  |  |  |  |  |  |  |  |  |  |
| No. of minutes | Quoted response | Std. | \% | Quoted response | Std. | \% | Quoted response | Std. | \% | Quoted response | Std. | \% |
| 3 min | 0.56 | 0.01 | 28 | 0.64 | 0.01 | 33 | 0.58 | 0.01 | 30 | 0.57 | 0.01 | 32 |
| 10 min | 1.19 | 0.01 | 61 | 1.26 | 0.01 | 64 | 1.20 | 0.01 | 59 | 1.16 | 0.01 | 63 |
| 20 min | 1.62 | 0.01 | 79 | 1.67 | 0.01 | 87 | 1.64 | 0.01 | 79 | 1.58 | 0.01 | 86 |
| 30 min | 1.81 | 0.01 | 88 | 1.83 | 0.01 | 94 | 1.81 | 0.01 | 88 | 1.74 | 0.01 | 93 |
| 60 min | 1.95 | 0.01 | 98 | 1.96 | 0.01 | 99 | 1.96 | 0.01 | 96 | 1.87 | 0.01 | 95 |
| Non-shortable stocks |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 min | 0.52 | 0.01 | 24 | 0.44 | 0.01 | 20 | 0.48 | 0.01 | 23 | 0.30 | 0.01 | 15 |
| 10 min | 1.15 | 0.01 | 54 | 1.12 | 0.01 | 50 | 1.07 | 0.01 | 51 | 1.00 | 0.01 | 42 |
| 20 min | 1.55 | 0.01 | 73 | 1.58 | 0.01 | 69 | 1.50 | 0.01 | 74 | 1.43 | 0.01 | 64 |
| 30 min | 1.71 | 0.01 | 85 | 1.88 | 0.01 | 82 | 1.63 | 0.01 | 80 | 1.80 | 0.01 | 79 |
| 60 min | 1.89 | 0.01 | 90 | 2.04 | 0.01 | 91 | 1.81 | 0.01 | 90 | 1.96 | 0.01 | 86 |



Fig. 5. Cumulative impulse response in the number of trades (market up day).


Fig. 6. Cumulative impulse response in the number of trades (market down day).


Fig. 7. Cumulative impulse response in the number of trades (daily return up day).
market days. When daily stock returns are used as an indicator for up and down market days, the results are similar. All the coefficients are statistically different between shortable and non-shortable stocks.

Overall, the results show that for both firm-specific (private/ public) information and market-wide information, the speed of price adjustment for shortable stocks is faster than non-shortable stocks on both up and down market days, while on down market days the short sale effect is more significant. ${ }^{13}$

[^10]

Fig. 8. Cumulative impulse response in the number of trades (daily return down day).

### 6.2. The effect of removal from the D-List

Stocks that no longer meet the D-list criteria are removed from the list, thereby becoming no longer shortable again. The stocks removed from the D-list represent an interesting subsample to confirm the robustness of our findings. Using the sample of stocks that are removed from the D-list, we examine the speed of price adjustment before and after they become nonshortable. A total of 66 stocks belong to this category. The results are consistent with the main findings. The trade continuity is weaker and quote reversals are stronger for stocks before they become non-shortable. It takes 10 trades or 30 min to attain $95 \%$ of the total price adjustment when the stocks are shortable but it takes 15 trades or 60 min to achieve the same level of price adjustment after they become non-shortable. The information parameters are much larger when they are shortable (6.89) than when they become non-shortable (5.55). The DELAY measure is 0.56 when they are on the D -list but it deteriorates to 0.61 after they leave the D-list. ${ }^{14}$

### 6.3. The option effect on the speed of price adjustment

Earlier studies demonstrate that the introduction of option trading enhances the speed of price adjustment to new information because option trading can be used as an alternative to short selling but at a lower cost. Manaster and Rendleman (1982) show that option trading improves the speed of price adjustment to new information. DV (1987) also predict that the existence of option trading reduces the cost of short selling, thus affect the efficiency of the price adjustment. Patell and Wolfson (1984), Jennings and Starks (1986), Senchack and Starks (1993), and Figlewski and Webb (1993) also provide empirical evidence in support of this hypothesis. In contrast, Mayhew and Mihov (2004) find no evidence that investors take advantage of newly listed options to take short positions, casting doubt on the past theories that a marginal change in the cost of short selling can have significant impact on stock prices. Our analysis in this section provides some insight into this empirical issue.

A total of 35 stocks are identified for having individual options and futures written. We contrast between shortable stocks with (35) and without (147) options and futures trading by re-estimating VAR regressions, PAM model, and Dimson beta regressions. Table 9 summarizes the results. The results show optioned shortable stocks have much weaker trade continuity and stronger

[^11]Table 8
Up and down day speed and delay measures. This table reports the speed and delay measure in up and down days. The up and down market days and the up and down days are defined as in Table 7, Panel A reports the speed measure and the information level from the PAM model in Table 5 Eq. (2). Panel B reports the delay measure and the contemporaneous adjustment from the Dimson beta regression Eq. (4). $P$-Values in the parentheses indicate the significance of the coefficients. $P$-Values of the equality-test tests the equality of the speed measure of shortable and non-shortable stocks in different periods.


Table 9
Stocks with and without options trading. Panel A reports the results of the VAR model. Panel B reports the results of the PAM model and Panel C presents the results of the Dimson beta regression and the delay measure. All the regressions are estimated for shortable stocks with options and shortable stocks without options. There are 35 stocks that are shortable with options and 147 stocks that are shortable but without options. $P$-Values in the parentheses test the significance of the coefficients and $P$-value in the last row under each coefficient tests the equality of estimated coefficients between the shortable stocks with and without options trading.

|  | With options trading |  | Without options trading |  |  | With options trading |  | Without options trading |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Coeff. | $P$-Value | Coeff. | $P$-Value |  | Coeff | $P$-Value | Coeff. | $P$-Value |
| Panel A: estimation results of the VAR regression |  |  |  |  |  |  |  |  |  |
| a1 | -0.17 | (0.0001) | -0.14 | (0.0001) | c1 | -0.13 | (0.0001) | -0.10 | (0.0001) |
| a3 | -0.05 | (0.0001) | -0.03 | (0.0001) | c3 | -0.03 | (0.0001) | -0.02 | (0.0001) |
| a5 | 0.00 | (0.2501) | 0.00 | (0.0001) | c5 | 0.01 | (0.0246) | 0.01 | (0.0312) |
| $P$-Value of equality-test | (0.0002) |  |  |  | $P$-Value of equality-test | (0.0001) |  |  |  |
| b0 | 0.42 | (<0.0001) | 0.39 | (<0.0001) |  |  |  |  |  |
| b1 | 0.35 | (0.0001) | 0.31 | (0.0001) | d1 | 0.28 | (0.0001) | 0.33 | (0.0001) |
| b3 | 0.07 | (0.0001) | 0.05 | (0.0001) | d3 | 0.07 | (0.0001) | 0.08 | (0.0001) |
| b5 | 0.01 | (0.0430) | 0.01 | (0.0221) | d5 | 0.01 | (0.0001) | 0.05 | (0.0001) |
| $P$-Value of equality-test | (0.005) |  |  |  | $P$-Value of equality-test | (0.002) |  |  |  |
| $\bar{R}^{2}$ | 0.08 |  | 0.11 |  | $\bar{R}^{2}$ | 0.32 |  | 0.26 |  |
| Panel B: estimation results of the PAM |  |  |  |  |  |  |  |  |  |
|  | $\gamma$ (speed measure) |  |  |  | $\alpha$ (information level) |  |  |  | $\bar{R}^{2}$ |
| With options trading |  | 0.84 |  | (0.003) | 6.92 |  | (<0.0001) |  | 0.31 |
| Without options trading |  | 0.58 |  | (0.019) | 3.53 |  | (<0.0001) |  | 0.17 |
| $P$-Value of equality-test |  | (0.002) |  |  | (<0.0001) |  |  |  |  |
| Panel C: estimation results of the Dimson beta regression and the delay measure |  |  |  |  |  |  |  |  |  |
|  | With options trading |  |  |  | Without options trading |  |  | $P$-Value of equality-test |  |
| $b_{\text {i, } 0}$ |  |  |  |  | 0.70 |  |  | (0.0001) |  |
|  | (<0.0001) |  |  |  | (<0.0001) |  |  |  |  |
| $\sum_{k=1}^{5} \beta_{i, k}$ |  | 0.03 |  |  | 0.10 |  |  | (0.0001) |  |
|  |  | (0.8048) |  |  | (<0.0001) |  |  |  |  |
| DELAY |  |  |  |  |  |  |  |  |  |
|  | (0.0001) |  |  |  | (<0.0001) |  |  | (0.0001) |  |
| $\bar{R}^{2}$ | 0.12 |  |  |  | 0.12 |  |  |  |  |

quote reversals than non-optioned shortable stocks. Optioned shortable stocks take less than eight trades or 20 min to adjust $95 \%$ of the total price adjustment, while non-optioned shortable
stocks take 10 trades or more than 30 min to accomplish same price adjustment. The speed measure (DELAY) for optioned shortable stocks is 0.84 ( 0.37 ), which is significantly greater (smaller)

Table 10
Determinants of speed of price adjustment. Panel A summarizes the speed measure from Eq. (2) and the delay measure from Eq. (4). Panels B and C report estimated coefficients of two OLS regressions (5). For the dependent variable, we introduce: (i) the speed measure constructed from the PAM model defined by Eq. (2); and (ii) the delay measure from the Dimson beta regression Eq. (4).
$Y_{i}=\alpha_{i}+\delta_{1, i}$ ShortVol $+\delta_{2, i}$ TradVol $+\delta_{3, i}$ Size $+\delta_{4, i}$ Price $+\delta_{5, i}$ OptDm $+\delta_{6, i}$ ShortDm $+\delta_{7, i}$ Iliquid $+\varepsilon_{i}$
where size is measured by market capitalization; ShortVol is the average daily short selling volume; TradVol is the average daily trading volume; price is the average price per share; illiquidity is measured by the Amihud (2002) ratio; OptDm is the dummy variable equals 1 if an option is written on the stock and 0 otherwise; and ShortDm is the dummy variable equals 1 if the stock is shortable and 0 otherwise. There are 816 stocks in total, including 634 stocks that were never on the D-list and 182 stocks that have been added to the D-list in the study period.

| Speed measure |  |  | Delay measure |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Panel A: summary of speed measures |  |  |  |  |  |
| Whole ma |  |  |  |  |  |
| 634 Neve |  |  |  |  |  |
| 182 Short |  |  | $\begin{aligned} & \text { On D-list } \\ & 1.02 \end{aligned}$ | Not on D-list $0.54$ | $\begin{aligned} & \text { On D-list } \\ & 0.38 \end{aligned}$ |
| $P$-Value of |  |  |  |  |  |
| Panel B: speed OLS estimation |  |  |  |  |  |
|  | Shortable | $P$-Value | Non-shortable | $P$-Value | $P$-Value of equality-test |
| ShortVol | 1.87 | (<0.0001) | -0.002 | 0.83 | (<0.0001) |
| TradVol | 0.69 | -0.002 | 0.73 | 0.005 | 0.71 |
| Firm size | -0.13 | -0.019 | -0.1 | -0.02 | 0.36 |
| Price | -0.004 | -0.243 | 0.007 | 0.43 | 0.13 |
| OptDm | 0.43 | (<0.0001) | 0.41 | (<0.0001) | 0.47 |
| ShortDm | 1.06 | (<0.0001) | 0.004 | 0.57 | (<0.0001) |
| Illiquid | -1.68 | (<0.0001) | -1.41 | (<0.0001) | 0.29 |
| $\bar{R}^{2}$ | 0.48 |  | 0.41 |  |  |
| Panel C: delay OLS estimation |  |  |  |  |  |
|  | Shortable | $P$-Value | Non-shortable | $P$-Value | $P$-Value of equality-test |
| ShortVol | -2.38 | (<0.0001) | 0.001 | 0.53 | (<0.0001) |
| TradVol | -0.53 | -0.0001 | -0.62 | -0.0001 | 0.45 |
| Firm size | 0.11 | -0.017 | 0.2 | 0.008 | 0.27 |
| Price | 0.001 | -0.215 | 0.004 | 0.11 | 0.39 |
| OptDm | -0.16 | (<0.0001) | -0.17 | (<0.0001) | 0.77 |
| ShortDm | -1.44 | (<0.0001) | 0.002 | 0.74 | (<0.0001) |
| Illiquid | 1.88 | (<0.0001) | 1.63 | (<0.0001) | 0.54 |
| $\bar{R}^{2}$ | 0.35 |  | 0.32 |  |  |

than 0.58 ( 0.51 ) computed for non-optioned shortable stocks. ${ }^{15}$ Overall, the findings strongly support the hypothesis that options/ futures trading enhance market efficiency by improving the speed of stock price adjustment to new information. The results also imply that reduced short sale costs speed up the price adjustment to new information as DV predict.

### 6.4. The impact of firm characteristics on the speed of price adjustment

Previous studies identify some factors such as firm size (Lo and MacKinlay (1990)), trading volume (Chordia and Swaminathan (2000)), option trading (Jennings and Starks, 1986; Senchack and Starks, 1993) that influence the speed of price adjustment. Taking advantage of the scalar speed measure and the delay measure and the daily short sale volume released by the HKEx, we examine the impact of firm characteristics on the speed of price adjustment: firm size, trading volume, option trading, stock price level, short selling volume, and short selling allowance. We run the following OLS regression using a total of 816 stocks, including 634 stocks that were never eligible for short sales, 182 stocks that have been added into the D-list during the study period, including the original sample of 147 stocks and the 35 stocks with options trading.

$$
\begin{align*}
Y_{i}= & \alpha_{i}+\delta_{1, i} \text { ShortVol }+\delta_{2, i} \text { TradVol }+\delta_{3, i} \text { Size }+\delta_{4, i} m \\
& +\delta_{5, i} \text { OptDm }+\delta_{6, i} \text { ShortDm }+\delta_{7, i} \text { Illiquid }+\varepsilon_{i} \tag{5}
\end{align*}
$$

[^12]For the dependent variable, we introduce: (i) the speed measure constructed from Eq. (2); and (ii) the delay measure from Eq. (4). For independent variables, size is measured by market capitalization; ShortVol is the average daily short selling volume; TradVol is the average daily trading volume; price is the average price per share; illiquidity is measured by the Amihud (2002) ratio; OptDm is the dummy variable equals 1 if an option is written on the stock and 0 otherwise; and ShortDm is the dummy variable equals 1 if the stock is shortable and 0 otherwise. For each speed measure, we estimate the regression for two periods: a period before the stocks are added to D-list and the period after. The results of the OLS regressions are reported in Table 10.

Panel A reports speed and delay measures. Shortable stocks have the fastest speed (1.02) and shortest delay ( 0.38 ), while those stocks which were never on the D-list exhibit the lowest speed ( 0.31 ) and longest delay ( 0.92 ). Panels B reports the OLS regression for speed measure. For shortable and non-shortable period, the coefficient of trading volume is 0.69 and 0.73 , respectively, both are significant, which is consistent with Chordia and Swaminathan's (2000) findings that high-volume stocks respond faster to new information than low-volume stocks. The coefficient of firm size is -0.13 and -0.10 , implying that the smaller firms respond faster to new information than larger firms. The illiquidity ratio is significantly and negatively related to speed and significantly positively related to delay, which indicates that liquid stocks enjoy the faster speed of adjustment. Option dummy, daily short selling volume and ShortDm all significantly and positively affect the speed measure. The last column reports the $P$-value of the equal-ity-test of the coefficients estimated when stocks are shortable and not-shortable. Only the coefficients of ShortVol and ShortDm are significantly different between the two cases, but all other
coefficients are not different. The results for the delay measure are about the same. The overall conclusion is that short sale restrictions significantly delay the speed of price adjustment to new information.

## 7. Conclusion

Taking advantage of the unique features afforded by the HKEx where only a designated group of stocks can be sold short and short interests are released daily, we measure the speed of price adjustment for the stocks before and after they join the D-list. Using trade-by-trade data, we investigate the speed of price adjustment to the information contained in each trade (including firm-specific private and public information) and to market-wide information for the stocks before and after they become shortable. Our major findings include: first, short sales speed up the price adjustment to not only firm-specific private/public but also mar-ket-wide information. Second, short sales speed up the price adjustment in not only down market but also up market days. Third, short sales enhance information efficiency by reducing trade continuity and increasing quote reversals. Additionally, shortable stocks incorporate more information in each trade. Hence, short sales significantly enhancing overall market efficiency. The costs of these benefits have yet to be investigated, which will be a future study in this topic area.

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[^1]:    ${ }^{1}$ Bris et al. (2007) also focus on public information by demonstrating a slower price adjustment with short sales restrictions in place rather than measuring the speed itself.

[^2]:    ${ }^{2}$ Hasbrouck (1991) finds that strong trade continuity is consistent with lagged adjustment to new information. In order words, weaker trade continuity lead to faster adjustment to new information.

[^3]:    ${ }^{3}$ Securities traded in the OTC markets including NASDAQ Small Cap, OTC Bulletin Board, and OTC Pink Sheets are not subject to short sale restrictions.
    ${ }^{4}$ Endo and Rhee (2006) provide a good summary of institutional aspects of margin transactions (margin purchases and short sales) in emerging markets.
    ${ }^{5}$ In a "naked" short sale, the seller does not arrange to borrow the securities in time to make delivery to the buyer within the standard settlement period. The HKEx prohibits investors from short selling a security without borrowing it before selling short. A breach of the rule is considered a criminal offence.

[^4]:    ${ }^{6}$ Please refer to the HKEx's web page at: http://www.HKEx.com.hk for full descriptions of the selection criteria for designated securities. A brief presentation of the requirements is also found in Chang et al. (2007).

[^5]:    ${ }^{7}$ For detailed explanations regarding the dynamic unrestricted VAR, please refer to Hasbrouck (1991).

[^6]:    ${ }^{8}$ We are grateful to the referee for suggesting us to add Figs. 1 and 2 along with necessary interpretation.
    ${ }^{9}$ Our evidence reported here is an interesting way of demonstrating the consequences of overvaluation without worrying about an asset pricing model's validity (Mazouz et al., 2009).

[^7]:    ${ }^{10}$ For detailed explanations on the PAM, please refer to Jones and Lipson (1999).

[^8]:    ${ }^{11}$ Dimson's (1979) original model has both lagged and lead betas variables, we use only lagged betas following Chordia and Swaminathan (2000).

[^9]:    ${ }^{12}$ The Hang Seng Index is the most popular stock market index in Hong Kong. It is a value-weighted index and its 40 component stocks account for approximately $2 / 3$ of market capitalization of the HKEx.

[^10]:    ${ }^{13}$ Our results provide an interesting contrast to what has been reported by Nilsson (2008) on the basis of Swedish options. He demonstrates that short sales constraints increase the deviations from put-and-call parity in the direction corresponding to a short position in the stock, while no such increase is found for deviations from put-and-call parity where a long position in the underlying stock is required.

[^11]:    ${ }^{14}$ The empirical results are available upon request.

[^12]:    ${ }^{15}$ The study period for each stock is from the day it has been added on the D-list to either the day it has been removed from the D-list or the last day of our study period (December 31, 2004), whichever comes first. Because of the difference in study periods, the results compiled in Table 9 are not the identical to those reported in Tables 3 and 4 but the overall findings are consistent.

