Price Limit Performance: Evidence from Transactions Data and the Limit Order Book*

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In recent years, organized stock exchanges with daily price limits adopted wider limits as narrower limits were criticized for jeopardizing market efficiency. This study examines the impact of a wide price limit on price discovery processes, using the data from the Kuala Lumpur Stock Exchange. Specifically, examined is the impact of daily price limits on (i) information asymmetry; (ii) arrival rates of informed traders; and (iii) order imbalance. Using both trade-to-trade transaction data and the limit order book, we compile evidence that price limits do not improve information asymmetry, delays arrival of informed traders, and exacerbates order imbalance. These results suggest that price limits on individual securities do not improve price discovery processes, but impose serious costs even when the limit band is as wide as 30 percent.

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"Hello, my name is (deleted) and I am an official from the stock exchange of (deleted). I have a question for the distinguished panelists. Our stock exchange is seriously considering the adoption of price limit mechanisms to protect our markets. Can anyone tell me what price limit level we should use?" One panelist replied: "To be honest, I don't think anyone knows the answer to that question," while another panelist offered: "In my opinion, not using any price limit is best, but a very wide or liberal price limit may be okay."

- The above exchange (paraphrased) took place at the Fourth International Forum of the Alternative Structures for Securities Markets conference held at Georgetown University on September 10-11, 1998. The theme of the conference was "Practical Implications of Applied Research for Emerging Market Microstructure." Stock exchange, regulatory, and government officials from over 40 countries, along with numerous U.S. academicians, were in attendance.

1. Introduction

In the securities markets, daily price limits represent literal boundaries on where individual security prices are allowed to move, often both upward and downward, and they are typically pre-specified by a percentage based on a previous trading session's closing price. Such price limit mechanisms are employed in the U.S. futures markets, but they are also used in many stock exchanges around the world, including Austria, Belgium, France, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Spain, Switzerland, Taiwan, and Thailand (Roll, 1989; Rhee and Chang, 1993). Despite their significant presence, however, Harris (1998) contends that we still don't know enough about these market mechanisms to make informed decisions regarding market regulation. Harris (1998) states that appropriate study samples using U.S. data are difficult to obtain. For example, most price limit studies using U.S. futures market data are only able to employ a few contracts (e.g., Chen, 1998; Ma, Rao, and Sears, 1989), which hinders cross-sectional analyses. Consequently, France, Kodres, and Moser (1994) state that there are many unanswered questions regarding price limit mechanisms. In our paper, we attempt to provide some much-needed insight into the effects of price limits by investigating transactions data and the limit order book of a stock market that imposes a daily price limit on its individual securities.[1] Specifically, we study the price limit system of the Kuala Lumpur Stock Exchange (KLSE) of Malaysia.

The primary impetus for studying the KLSE stems from the following three reasons: First, we wish to study a market with a wide price limit. The KLSE uses a 30 percent price limit per trading session. This limit band is much wider than most other exchanges. Recently, several papers have examined the impacts of narrow price limits and have found them to be overly restrictive. For example, Chen (1997) examines Taiwan's previous seven percent price limit, Chen (1998) and Park (2000) study the relatively narrow price limits of the U.S. futures markets, Kim and Rhee (1997) investigate the narrow limits of the Tokyo Stock Exchange, and Phylaktis, Kavussanos, and Manalis (1999) examine the 4-8 percent price limit of the Athens Stock Exchange. All of these researchers find potential problems with price limits. However, based on their research, we don't really know whether *narrow* price limits are bad, or if price limits per se are bad. A policy question that is often raised is "if price limits are to be adopted, then what is the appropriate level?" In fact, conventional wisdom even suggests that wide price limits may be harmless. For example, the Stock Exchange of Thailand recently increased their price limit from 10 percent to 30 percent, and the Korea Stock Exchange recently increased their price limit from 6 percent to 15 percent. Thus, the impact of wide price limits remains an important policy issue and a study of wide price limits brings out practical merits for market regulators and for academicians with regulatory policy research interests. The 30 percent price

[1] Recently, papers have begun studying the impacts of trading halts on individual stocks. For example, Christie, Corwin, and Harris (2000) and Lee, Ready, and Seguin (1994) study NASDAQ and NYSE imposed trading halts, respectively, and they both find that trading volume and volatility are higher after the halt. Corwin and Lipson (2000) argue that the lack of liquidity surrounding the halt causes the abnormal volatility. However, while the literature on trading halts can provide some hints into price limit effects, it's important to realize that halts differ from price limits in at least two significant ways. As pointed out by Kim and Sweeney (2000), (i) prices before a halt are not capped as they are with price limits and (ii) trading halts are not mechanically or predictably imposed, but are subjectively imposed under certain circumstances (e.g., due to impending news or an order-imbalance).

limit per trading session of the KLSE, therefore, should provide an important first step toward investigating this issue.

Second, we feel that findings from investigating the KLSE will have potential applicability toward other stock markets. In studies that examine stock market behavior from multiple countries, such as Aggarwal, Inclan, and Leal (1999), Bekaert, Harvey, and Lunblad (2000), Bekaert and Harvey (1997), DeSantis and İmrohoroğlu (1997), Goetzmann and Jorion (1999), Harvey (1995), and Rouwenhorst (1999), it is found that the Malaysian stock market behaves quite similarly (for example, with regard to volatility, turnover, etc.) to the markets of many other countries, including the European markets, most other Asian markets, most Latin American markets, and the developed markets, such as the U.K. and Japan. In these studies, it is usually the volatile markets of Argentina, Brazil, and Taiwan that stand out as being unique. Even in practitioner circles, the Malaysian stock market is considered to be well-developed and fairly liquid among emerging markets (e.g., see Posner, 1998). Therefore, our findings from the KLSE can be viewed as being both insightful and potentially applicable to many other markets.

Finally, among the few stock markets that we wished to study, the KLSE was the only one whose transaction data and limit order book data were available to us. Transactions data and/or limit order books from non-U.S. exchanges are difficult to obtain (and decipher), as reflected by the lack of non-U.S. market microstructure studies.[2] Therefore, while this paper contributes to the important expanding market microstructure literature, we also view the fact that our data allows us to study price limit effects at the microstructure level as extremely fortuitous. For example, rather than making inferences on market behavior using only daily data, we will be able to actually observe what happens just prior to, and immediately after, a price-limit-hit. As noted by Lehmann (1989) and Ma, Rao, and Sears (1989), it's difficult to

[2] A few exceptions include studies of the Tokyo Stock Exchange (Lehmann and Modest (1994), Hamao and Hasbrouck (1995), Ahn, Cai, and Hamao (2001)), the Taiwan Stock Exchange (Chang, Huang, Rhee, Shu (1999)), the Paris Bourse (Biais, Hillion and Spatt (1995), and recently the Hong Kong Stock Exchange (e.g., Ahn, Bae and Chan (2000)).

assess price limit effects when relying on only daily data. Finally, as pointed out by Harris (1998), the main reason why price limit studies are "quite scant" is primarily due to the lack of meaningful data.

Aside from examining the transactions data and limit order book of a market that employs a wide price limit, our research makes several other very important contributions. First, we examine the impact of price limits on information asymmetry. A popular justification for price limit mechanisms is that they moderate the effects of uncertainty and/or irrationality in the markets by imposing price boundaries. When an "irrational" price reaches its limit, it supposedly provides all traders with time to assess and to recognize the 'true' or equilibrium price (for example, the Tokyo Stock Exchange states that their price limits represent "time-out" opportunities). In this context, price limits are supposed to mitigate information asymmetry. However, Amihud and Mendelson (1987, 1991) and Gerety and Mulherin (1992) argue that rational equilibrium prices can only be realized through continuous trading. In addition, informed traders with private information may be unable or unwilling to reveal their information when price limits are hit simply because prices are not allowed to move beyond their limits (Kim and Rhee, 1997; Kim and Sweeney, 2000). Hence, price limits may not mitigate information asymmetry, but instead price limits may actually increase information asymmetry. We investigate this issue by examining the degree of information asymmetry before and after a price-limit-hit. If limit-hits do provide time for information dissemination and revelation, then the degree of information asymmetry should be reduced after the limit-hit. Our results, however, indicate that price-limit-hits do *not* reduce information asymmetry.

Our investigation of information asymmetry naturally leads to another, but related, empirical investigation. When the degree of information asymmetry is high, then there is more noise (uninformed) trading (French and Roll, 1986). Uninformed trading leads to price volatility that is unrelated to fundamental value, and thus undesirable. Miller (1991) refers to this harmful volatility as episodic volatility and Harris (1998) refers to it as transitory volatility. During times of uncertainty, if noise trading intensifies, then it may be useful to curb trading. However, the existence of price limits may just as likely exacerbate the noise-trading problem. Kim and Rhee (1997) and Kim and Sweeney (2000) conjecture that information-based trading does not take place during trading sessions when limit-hits occur because rational expectation prices cannot be realized. Instead, informed traders must wait for subsequent trading sessions when price limits have been revised, which mean that information revelation and price discovery is delayed. In the Kim and Rhee (1997) study, they examine price continuation and reversal behavior to see if price limits delay information-based trading. In our investigation, we conduct a much more direct investigation by comparing arrival rates of informed traders before and after a limit-hit. Overall, we find that arrival rates increase after a limit-hit, revealing a delay in information revelation.

A third empirical investigation focuses on order imbalance. On one hand, price-limit-hits can be induced by order imbalances as one-sided supply or demand will drive prices to the limit (Lehmann, 1989). In other words, order-imbalances lead to limit-hits. However, it is also possible that the existence of price limits may actually create or exacerbate order imbalances, which, in turn, lead to limit-hits. For example, traders may sub-optimally advance their trades in anticipation of a price-limit-hit, which then accelerates the price movement to the limit-hits.[3] If traders suspect that trading will cease when prices reach the upper (lower) limit, they will then buy (sell) frantically before the price-limit-hit occurs. This behavior suggests that volume will be one-sided prior to the limit-hit. In other words, the price limits themselves could cause order-imbalances.

To investigate the impact of price limits on order imbalances, we examine the KLSE order file just prior to and immediately after a limit-hit. We find order imbalances prior to the limit-hit. To test the possibility that the impending limit-hit actually caused this imbalance, we

[3] This possibility is analogous to Subrahmanyam's (1994, 1995) gravitational effect hypothesis with respect to trading halts.

look to the period immediately after the limit-hit and we find order imbalance reversals (i.e., an order imbalance exists, but in the other direction). This evidence reveals that traders are attempting to correct for (reverse) their earlier sub-optimal trades. If the pre-hit trades had been not sub-optimally executed in anticipation of an impending limit-hit, then an order imbalance during the *post*-limit-hit period would not have been observed. For example, for a control group that also experienced a large price change, but without a limit-hit, we do not find significant order imbalance reversals after their large price change. Overall, this evidence suggests that limit-hits disrupt the liquidity of the markets and cause order imbalances.

Finally, we should mention that the past empirical work on price limits have focused primarily on volatility. The recent literature is beginning to converge toward the opinion that price limits do not moderate volatility (for example, see Chen's (1998) and Park's (2000) studies on U.S. futures markets, Kim's (2001) study of the Taiwan Stock Exchange, Kim and Rhee's (1997) study of the Japanese market, and Phylaktis, Kavussanos, and Manalis's (1999) study of the Greek market). However, if excessive volatility is an outcome of irrational behavior and if price limits exacerbates this, as the literature suggests, then it may be just as important, if not more important, to focus on exactly why price limits cannot reduce harmful volatility. Prior papers do not explicitly investigate this issue, leaving the relationship between price limits and volatility as somewhat ambiguous. In our paper, we provide some important empirical evidence on the link between price limits and excessive volatility. If price limits do not reduce information asymmetry, but instead delays information trading and contributes to the order imbalance, then this reveals how and why price limits are ineffective in reducing transitory volatility. Therefore, what further differentiates our paper from others is that we address important questions that have been raised regarding price limits, but not yet been investigated.

The rest of this study is organized as follows. Section 2 discusses the institutional background of the KLSE. Section 3 describes our data and presents summary statistics.

Section 4 outlines our empirical design and findings. The last section summarizes the results and presents concluding remarks.

2. Institutional Background of the KLSE

Trading takes place five days a week (Monday-Friday), except on public holidays and other market holidays (when the Exchange is declared closed by the KLSE Committee). During the study period of 1995-1996, there are two trading sessions per market day: a morning session (9:30 a.m. – 12:30 p.m.) and an afternoon session (2:30 p.m. – 5:00 p.m.).[4] Orders are entered 30 minutes prior to the market open both in the morning and afternoon.

Like all other stock exchanges in Asia, the KLSE is a purely order-driven market conducted by brokers with no designated market makers or specialists. Trading on the KLSE was fully computerized in 1992 with the full implementation of the System on Computerized Order Routing and Execution (SCORE). SCORE has eliminated the need for a trading floor at the Exchange. Trading is facilitated through the Exchange's sixty-two member brokerage firms located all over the country. Brokerage companies are equipped with the KLSE's enhanced broker front-end system, WinSCORE, whereby each dealer operates from an integrated terminal providing real-time market information dissemination as well as order and trade routing and confirmation.

The KLSE uses the call market system to determine the matching price. The trading rules are as follows: (i) The match price at which the most number of shares can be executed; (ii) When there is more than one price at which the most number of shares can be executed, the price closest to the last traded price shall be the matching price; (iii) All buy orders quoted above the matching price and sell orders quoted below the matching price are executed at the matching price. Unexecuted or partially filled orders at the market's opening are left on the order book for subsequent call market trading. After the opening price is determined,

[4] Effective December 15, 1997, the morning trading session begins at 9:00 a.m. instead of 9:30 a.m.

subsequent orders are batched over various time intervals ranging from one to 90 seconds depending on a security's trading activity. Throughout the trading session, the same call market matching principle is used.[5]

Companies are listed on either the 'main' board or the 'second' board. At the end of 1996, a total of 621 companies (including 3 property trust funds) were listed on the KLSE. These include 413 companies on the main board and the remaining 208 companies on the second board.[6] Second board companies are generally younger and smaller in capitalization, with the average firm size being about one-sixth of main board companies.[7] At the end of 1996, the KLSE ranked 11th in the world in terms of market capitalization ($307 billion) and 15th in terms of annual turnover (66%).[8]

A daily price limit is a key institutional feature of the KLSE. The price limit is fixed at ±30 percent per trading session: the upper [lower] limit price for the current trading session is equivalent to 130% [70%] of the closing price of the last trading session. Therefore, if a stock consecutively hits the upper limit price in the morning and the afternoon sessions, the price could jump up [down] by as much as 69% [51%] in a day. As mentioned previously, this price limit band is extremely wide as compared to other stock exchanges: for example, Austria (5%), China (10%), France (7%), Greece (4-8%), Korea (15%), and Taiwan (7%).

3. Data and Summary Statistics

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[5] The only other Asian market that adopted a call market system throughout trading sessions is the Taiwan Stock Exchange. Refer to Chang, Huang, Rhee, Shu (1999) for a comparison between call and continuous auction methods.

[6] It should be noted that once foreign ownership of a company reaches 30 percent, the firm's shares is then traded on a Foreign Board. However, there are only a few such companies, e.g., Public Bank and Malaysian International Shipping Corporation (Kim, 1996).

[7] In addition, more than 100 securities of Malaysian companies were traded on Singapore's over-the-counter market, Clob International, during the study period but their volume was not significant (Kim, 1996).

[8] See *Emerging Stocks Factbook 1997* of the International Finance Corporation.

In this study, we use real-time transaction data (post-trade files) and the order flow data (pre-trade files) of the KLSE during a two-year period from January 3, 1995 to December 31, 1996. Due to the wide price limit band of ±30 percent, price limit-hits are not a daily affair. In total, we identify 170 cases of limit-hits during our study period.[9] A total of 110 limit-hits occurred during the morning trading session and the remaining cases were recorded in the afternoon trading session.

To conduct our study, we form two stock groups. The first stock group includes those stocks that actually hit the 30 percent limit, and they are denoted as LHG (Limit-Hit Group). For our second stock category, we identify those stocks that also experienced a dramatic price change (by at least 15 percent) from the previous session's closing price, but they do *not* hit a price limit. This latter stock group is denoted NHG (No-Hit Group) and it represents a very important control sample as we only identify these stocks during sessions when a limit-hit occurs. Furthermore, as Kim and Rhee (1997) point out, effects associated with limit-hits can be associated with either (1) the price limit or (2) the large price-change.[10] For example, if we observe delays in the arrival of informed trading for LHG stocks, we cannot be sure if this delay is due to the limit-hit or if it is due to the large price-change. Therefore, by identifying both LHG and NHG stocks, we have created study samples where all stocks experienced a large price change, but only some of the stocks actually hit their price limits. Any notable differences between LHG stocks and NGH stocks can then be associated with the price limit effect rather than a large-price-change effect.[11]

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[9] Of the 170 cases, only 5 of them hit the lower limits while the rest hit the upper limit. This is not surprising considering that KLSE enjoyed a bull market trend during the study period, especially in 1996.

[10] Lehmann (1989) and Miller (1989) make a similar point.

[11] For the NHG category, we considered alternative screens for inclusion such as 20% and 25% price changes, but these alternative screens significantly reduced sample sizes without changing the results.

In selecting the final study samples of both stock groups, a number of factors were considered. First, to conduct meaningful analyses, we require each stock to have at least one hundred trades within each trading session.[12] We also excluded stocks with limit-hits over consecutive sessions.[13] These screens reduced the LHG sample to 101 cases, out of which 98 cases were upper limit-hits. For our NHG sample, we identify 175 cases, out of which there were zero cases of price declines. Therefore, our final LHG sample only consists of upper limit-hit stocks (n=98) and our final NHG sample only consists of price increases (n=175).[14]

The sample sizes of the two stock categories are presented in Table 1 and broken down according to board (main board versus second board), year (1995 versus 1996), and trading session (morning versus afternoon). From this table, we observe that: (i) a majority of the limit-hits occur during 1996 (89 out of the 98 cases), (ii) the second board constitutes about two-thirds of the LHG sample, and (iii) 70% of the limit-hits occur in the morning trading session. Because the observations are not evenly distributed across boards, years, and trading sessions, we will incorporate dummy variables when we conduct our analyses to capture the possibility of an inherent effect associated with trading location (board), period (year) and time of day (session).

[Insert Table 1]

Table 2 reports descriptive statistics for our two stock groups. During the session of the large price change, LHG stocks have greater trading activities than NHG stocks. Specifically,

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[12] The number of trades during each limit-hit session varies from a single trade to a maximum of 7,314 trades.

[13] Without this screen, the results are qualitatively similar to those reported. However, because we will conduct an event-type study, we restrict our sample to where the event takes place in a single session to provide unambiguous results, and to make comparisons to our control group meaningful.

[14] We acknowledge that samples that only include price increases represent a weakness to our study, but we feel confident that our findings will be reliable and informative because Kim and Rhee (1997) find that upper and lower price limits affected stocks in similar ways.

LHG stocks record, on average, higher trading volume and value, a larger number of trades, and higher turnover ratios than NHG stocks. LHG stocks are also larger than NHG stocks with regard to market capitalization. Therefore, to incorporate the possibility that differences in trading activity and firm size may explain differences between LHG and NHG stocks, rather than the limit-hits themselves, we include a trading activity variable and a firm size variable as controls when we conduct our comparative analyses between the two stock groups.

[Insert Table 2]

Once stock prices hit the limit, they are not allowed to move beyond the limits. However, trades may still be executed if there are matching buy and sell prices during each call market batch-matching. Table 3 reports on the duration of the limit-hit for LHG stocks. Within the same trading session when limit-hit occurs, duration is measured from the time when the stock first hits its limit to the last moment the price stays at the limit, i.e., prior to the emergence of a new price or until the close of the trading session. There are also instances of multiple limit-hits within a session. For these instances, we consider the limit-hit to be in effect from the first limit-hit until the last moment the price stays at the last limit-hit or until the close of the trading session, even though there were price bounces.[15]

[Insert Table 3]

As summarized in Table 3, the duration of limit-hits ranges from 0.20 minutes to 179 minutes with an average of 63 minutes. Limit-hits occurring in the morning trading session tend to last longer than those that occur in the afternoon session (71 minutes vs. 45 minutes). This may be due to the morning trading session being 30 minutes longer than the afternoon session. Also, limit-hits that occur in the earlier part of the trading session tend to have longer limit-hits.[16]

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[15] The bounces in prices within the limit-hit are considered to be due to bid-ask bounce or transitory prices moving towards equilibrium.

[16] The correlation between the time-length from the session opening to the first limit-hit and the duration of limit-hit is significantly negative at -0.65.

Due to the large variation in duration, we cannot neglect the possibility that it may be an important variable when we conduct our analyses. Hence, a duration variable is included when we conduct our comparative analyses between the two stock groups.

4. Empirical Test Design and Findings

4.1. Test Design

To conduct our empirical investigations, we use an event-study type approach. The event session when a limit-hit occurs is defined as S_0, whereas the session prior to S_0 is signified by S_{-1}, and the session immediately after the limit-hit by S_{+1}. Therefore, we can conveniently form three subperiods surrounding each limit-hit: (1) the pre-hit period, which is defined from the beginning of S_{-1} to the first limit-hit in S_0; (2) the limit-hit period, which takes place in S_0; and (3) the post-hit period, which is defined from the end of the limit-hit period in S_0 to the end of S_{+1}. For NHG, S_0 is the session of the large price change, which is defined by a change of at least 15% but less than 30%. In addition, for NHG, S_0 is also the same session where another stock experienced a limit-hit. Therefore, the identification and length of the pre-periods and post-periods for NHG stocks are also determined by when limit-hits take place.

We wish to examine if price limits affect (i) the degree of information asymmetry; (ii) the arrival rate of informed traders; and (iii) the extent of order imbalances. In order to conduct these investigations, therefore, we will compare each of these characteristics from the pre-hit period to the post-hit period to see how limit-hits affect each one of them. Furthermore, to determine whether or not the change is significant, we will use pre-to-post changes of NHG stocks as a benchmark. Just like with LHG stocks, NHG stocks also experience a large price change during the same session, but NHG stocks do not experience a limit-hit. Thus, if we observe an effect in LHG stocks that is absent in NHG stocks, then the effect can be associated to the limit-hit.

However, we are fully aware that simply comparing these pre-to-post-hit changes between LHG and NHG will lead to premature conclusions because, as we have seen from the summary statistics, there are many differences between LHG and NHG stocks. For example, we may observe declines in information asymmetry for LHG that is larger than declines in information asymmetry for NHG. At first blush, this may imply that limit-hits improved information asymmetry, however, because LHG stocks trade more frequently, because LGH stocks are bigger, etc., we cannot simply associate the improvements in information asymmetry to the limit-hit. Therefore, to ensure that the change in information asymmetry, arrival rates of informed traders, and order imbalance level is associated with the limit-hit itself, we model these changes as dependent variables in a regression setting with control variables. By doing this, we conduct a more meaningful mean-difference test between the pre- and post-hit periods. Specifically, the following regression model is used:

$$\Delta_j = \alpha_0 + \alpha_1 \cdot LHG_j + \alpha_2 \cdot BOARD_j + \alpha_3 \cdot YEAR_j + \alpha_4 \cdot SESSION_j + \alpha_5 \cdot TURNOVER_j + \alpha_6 \cdot SIZE_j + \alpha_7 \cdot DURATION_j + \eta_j, \quad (1)$$

where Δ_j denotes the vector of the changes in one of the following dependent variables: information asymmetry, arrival rates of informed traders, and order imbalance from the pre- to post-hit periods for stock j. LHG, BOARD, YEAR, and SESSION are dummy variables equal to 1 if stock j belongs to the limit-hit group (LHG), if stock j belongs to the second board, if the year is 1996, and if the trading session is the afternoon session, respectively, and 0 otherwise. TURNOVER is defined as the combined trading volume (in number of shares) in the pre- and post-hit periods divided by the total shares outstanding. SIZE captures a potential firm size effect and is defined as the natural logarithm of market capitalization. DURATION is the natural logarithm of the duration of the limit-hit, in minutes, from the first limit-hit occurrence until the last moment when the price stays at the limit. In the context of control variables, therefore, any time the LHG dummy variable is significant, we can then attribute significant pre-to-post-hit changes with the limit-hit. A more detailed discussion focusing on each of our three investigations follows.

4.2. Information Asymmetry

Price limit proponents suggest that limit-hits provide time for information resolution and transmission. Hence, limit-hits are posited to reduce information asymmetry and uncertainty in the markets. If price limits are effective in this regard, then the degree of information asymmetry should improve (i.e., decrease) after limit-hits. Thus, the following null hypothesis can be tested:

H_1: Price-limit-hits do not improve information asymmetry.

In measuring information asymmetry, we start with the Bayesian model of intraday price formation. This model was designed and empirically tested by Madhavan and Smidt (1991) and later applied by Choi and Subramanyam (1994).[17] In their model, the expected value of a stock is expressed as a combination of the prior mean, which reflects public information, and a noisy signal regarding private information contained in the current order flow. Formally, a revision in transaction price for stock j is given by:

$$\Delta PRICE_{jt} = \beta_0 + \beta_{1j}q_{jt} + \beta_{2j}D_{jt} + \beta_{3j}D_{jt-1} + \varepsilon_{jt} - \rho_j\varepsilon_{jt-1}, \qquad (2)$$

where $\Delta PRICE_{jt}$ represents the change in two consecutive transaction prices from time t-1 to t; q_{jt} is the signed transaction size, and D_{jt} is an indicator variable equal to +1 or –1 if the current price change was an increase or decrease, respectively. The ε's are white noise error terms and ρ_j, which denotes the first-order error auto-regressive correlation, is treated as a parameter for estimation.

[17] Hasbrouck (1991) provides another useful measure of information asymmetry that relies on bid and ask quotes. However, we are unable to use his approach because bid and asked quotes do not exist on the KLSE where no market makers exist to quote bid and ask prices.

From the Madhaven and Smidt (1991) model, we can extract an information asymmetry measure by calculating $SYMM_j = (|\beta_{3j}|/\beta_{2j})$. Because β_3 is the parameter coefficient for D_{jt-1}, which reflects prior beliefs, SYMM measures the weight placed by liquidity traders on the information content of the order flow. If order flow is uninformative (because the ratio of private to public information is small), then the weight is near unity. Conversely, with severe information asymmetries, the liquidity providers' beliefs are very sensitive to order flow, and the weight is negligible. Since no market markers exist on the KLSE, traders that place public limit orders are the ones providing liquidity on the KLSE. In other words, the larger the value of SYMM, the lower the information asymmetry.

We execute equation (2) separately for the pre- and post-hit periods for both LHG and NHG stocks.[18] If the price limit rule is effective in improving information asymmetry, then we will expect the values of SYMM to be higher (which implies lesser information asymmetry) in the post-limit-hit period for the LHG stocks. To identify the changes in the degree of information asymmetry from the pre- to post-hit period, we measure $\Delta SYMM_j = \log(SYMM_{j,post}/SYMM_{j,pre})$. These calculations are reported in Table 4.

[Insert Table 4]

As summarized in Panel A of Table 4, both LHG and NHG stocks report mean [median] increases in SYMM of 7.03% [4.91%] and 5.69% [2.86%], respectively. Because both groups of stocks record increases, the reduction in information asymmetry cannot be attributed to price limits alone. In addition, we cannot say with confidence that the larger improvement in information asymmetry for LHG stocks is due to the limit-hit because there are several other differences between LHG and NHG stocks. Therefore, to conduct a meaningful mean difference test, we rely on the multiple regression as defined by equation (1) and we use

[18] We require at least 30 prices for model estimation; otherwise SYMM is treated as a missing value.

$\Delta SYMM_j$ as the dependent variable.[19] If the reduction in the degree of information asymmetry for LHG stocks is indeed caused by price limits, then the coefficient for the LHG dummy variable should be positively significant. The regression results are reported in Panel B of Table 4. The estimated coefficient of LHG is positive (0.0191) but not significant. Thus, the result does not support the view that price limits reduce information asymmetry. The estimated coefficient of SESSION is negative, signifying that limit-hits in the afternoon trading session do not necessarily reduce information asymmetry. The turnover ratio, board listing, size, and year do not show any significant impact on the change in information asymmetry. Overall, based on these results, we cannot reject the null hypothesis, H_1. While we do observe reductions in information asymmetry, we cannot associate it with the limit-hit.

4.3. Informed Trades

An impending limit-hit may keep informed traders away due to the price constraints that exist during the pre-hit period. Here, price limits would delay information revelation and price discovery because informed traders enter the market *after* a limit-hit has taken place. Thus, the following null hypothesis can be tested:

H_2 : *The arrival rate of informed traders remains unchanged after limit-hits.*

The arrival rate of informed traders is one of four parameters in a model developed and tested by Easley, Kiefer, O'Hara, and Paperman (1996).[20] Using the total number of buy and

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[19] Note that SYMM is a ratio of coefficients from equation 2. Therefore, if there is a measurement error problem with the explanatory variables in equation 2, then it is possible that the SYMM variable for any particular security is misspecified. However, even if we use SYMM as a dependent variable in a separate regression, we will still obtain estimated coefficients that are asymptotically consistent. Assume that the observed dependent variable Y (which is estimated as $\log(SYMM_{j,post}/SYMM_{j,pre})$ in our regression) equals the true Y* plus error ν. Then, we can rewrite this equation as $Y = Z\gamma + \varepsilon + \nu$ since the true equation is $Y^* = Z\gamma + \varepsilon$. Then $Y = Z\gamma + \mu$ where $\mu = \varepsilon + \nu$, and $cov(Z, \mu) = cov(Z, \varepsilon + \nu) = 0$. Thus, the assumption of OLS is not violated.

[20] In the Easley et al. (1996) model, the probability of information-based trading in a stock is a function of four parameters: α = the probability of an information event; δ = the probability that the new information is bad news; μ = the arrival rate of informed traders; and ε = the arrival rate of uninformed traders.

sell orders, each of these parameters can be estimated from a likelihood function. Thus, their model provides a convenient and readily applicable estimation method for the arrival rate of informed traders. The data used for our investigation are obtained from the KLSE order (pre-trade) file that consists of the entire public limit order book of buy and sell orders during the two-year study period. In the absence of market makers or dealers, liquidity on the KLSE is provided solely by public limit orders.

We first tally the number of buy and sell orders during each two-minute interval for all of the LHG and NHG stocks. Using the Easley, et al. (1996) model specification, the parameters of the trade process for each stock in our sample are then estimated by maximizing the likelihood function conditional on the stock's order flow data using a non-linear programming (NLP) procedure.[21] From this procedure, we extract the parameter estimate, μ, that measures the arrival rate of informed traders. In the next step, we compute the change in the arrival rate of informed traders from the pre- to post-hit periods for each stock. This change, denoted by $\Delta ARIV_j = \log(\mu_{j,post}/\mu_{j,pre})$, is used as a dependent variable in equation (1) to conduct a mean difference test between LHG and NHG stocks. The regression result is presented in Table 5.

[Insert Table 5]

As summarized in Panel A of Table 5, LHG stocks show a mean [median] increase of 16.04% [23.4%] in the arrival rates of informed traders, while the NHG stocks show a 6.70% [22.48%] decline. Regression results are presented in Panel B. From the regression results, we observe that the estimated coefficient of LHG is positive and significant. Thus, we reject the null hypothesis, H_2, because (1) we do observe an increase in the arrival rate of informed traders after limit-hits and (2) the significant LHG coefficient from the regression results reveals that this increase is specifically associated with the limit-hit. Some informed traders have to wait

[21] Specifically, NLP is a general nonlinear programming procedure that can maximize a general function subject to linear equality or inequality constraints. The benefit of using NLP is that it is a user-defined likelihood function. The SAS/ETS User's Guide provides additional information on this procedure.

for the resumption of trading to incorporate their private information into stock prices. Thus, it is during the post-hit period, when new limits are allowed, that the informed traders enter the markets and trade on their private information. This finding indicates that price limits do not serve its main purposes of facilitating information resolution and reducing information asymmetry. Instead, price limits appear to delay the arrival of information, which delays the price discovery process.

4.4. Order Imbalance

Price limit advocates argue that limit-hits provide time to allow the market to absorb massive one-sided volume (i.e., to correct order imbalances). However, a potentially ironic outcome of price limits is that they could just as easily be the cause of the order imbalance. If traders know that trading will be stopped when prices reach the upper [lower] limit, they will then buy [sell] frantically before the circuit breaker is triggered, this suggests that volume will be one-sided, which, in turn, will actually accelerate the price movement to the limit. Based on this discussion, if price limits cause order imbalances, then we should observe a reversal in the order imbalance after the limit-hit (i.e., during the post-hit period). That is, traders will wish to reverse their sub-optimal trades from the pre-hit period. If this is observed, then note that price limits are actually causing order imbalances prior to, and after, a limit-hit. To examine this possibility, we will test the following null hypothesis:

H_3: The order imbalance remains unchanged after limit-hits.

We measure order imbalance, IMBAL, as the ratio of buy orders to total orders, with regard to the number of shares. If this ratio is 0.5, then demand equals supply. A ratio greater than 0.5 implies that there are more buys than sells, creating an upward price pressure. During the pre-hit period, if price limits induced order imbalances, then we expect LHG stocks to have an IMBAL ratio greater than 0.5. During the post-hit period, however, LHG stocks are expected to experience a significant order imbalance in the other direction (more sells than buys) as traders will try to reverse their earlier sub-optimal trades. For NHG stocks, in the absence of an impending limit-hit, there should be no order imbalance reversals.

Summarized below are the estimates of order imbalance for both LHG and NHG stocks. As expected, LHG stocks have a mean IMBAL ratio of 0.5386 in the pre-hit period, and this ratio declines to 0.4515 in the post-hit period. While the order imbalance *prior to* the limit-hit may or may not reveal a "magnet" effect (i.e., where sub-optimal trades are being made in anticipation of a limit-hit), the order imbalance reversal *after* the limit-hit suggests that a magnet effect did take place during the pre-hit period. Interestingly, NHG stocks show IMBAL ratios less than 0.5 during both the pre- and post-hit periods, but there is no order imbalance reversal from the pre-hit to the post-hit period, consistent with our expectations.[22]

Period		LHG Stocks	NHG Stocks
Pre-Hit Period	Mean	0.5386	0.4622
	Median	0.5111	0.4567
Post-Hit Period	Mean	0.4515	0.4228
	Median	0.4356	0.4216

To verify that the LHG's order imbalance reversal is specifically associated with the limit-hit, we first estimate a new variable, $\Delta IMBAL_j = \log(IMBAL_{j,post}/IMBAL_{j,pre})$, where $\Delta IMBAL_j$ represents the change in order imbalance from the pre-hit period to the post-hit period, and it is used as the dependent variable in model (1). If the limit-hit did cause the order imbalance reversal, which would confirm a magnet effect, then the estimated coefficient for the LHG dummy variable should be negative and significant. The regression result is presented in Table 6.

[Insert Table 6]

As summarized in Panel A of Table 6, the cross-sectional mean [median] of $\Delta IMBAL_j$ are -16.22% and -8.36% for the LHG and NHG stocks, respectively. Since both groups show the decline in the degree of order imbalance, the critical question is whether the LHG variable in the multiple regression will have a significant negative coefficient. As reported in Panel B, the limit-hit is responsible for the order imbalances experienced by LHG stocks during the pre- and post-hit periods. Thus, we may interpret that the price limits do not achieve the objective of cooling off the market. Rather, a magnet effect exacerbates the degree of order imbalance. The estimated coefficients of both SESSION and TURNOVER are positive and significant, indicating that limit-hits in the afternoon trading session, and stocks with higher turnover, experience a significant increase in buying pressure during the post-hit periods.

5. Conclusions

This paper studies the Kuala Lumpur Stock Exchange's 30 percent price limit system. Prior papers have criticized narrow price limits and, consequently, these studies can only suggest that narrow price limits, not price limits per se, are bad (which is a rather unsurprising finding). An 'optimal' price limit range, if it exists, could occur at wider price limits. By examining the KLSE's wide price limit band, we take an important first step towards addressing this issue. In addition, the KLSE is a useful market to study because it is not a unique or idiosyncratic market, as compared to most other markets (at least not that we are aware of), which makes us believe that our study's findings can be widely applicable to other markets. Finally, our study makes use of transactions data and the limit order book. Thus, we are able to contribute to the expanding market microstructure literature, while adding to the price limit literature with more meaningful data.

In this paper, we address new research questions regarding price limits. Specifically, we examine the impacts of price limits on information asymmetry, arrival rates of informed traders, and order imbalance. In conducting our study, we first identify a study sample of stocks that actually hit their price limit. By comparing the pre- and post-hit periods, we can then identify the

[22] All reported means are significantly different from 0.5 at the 1% level.

impact of the limit-hit. However, we are well aware that any observed differences between the pre- and post-hit periods could be associated to (i) the price-limit-hit or (ii) the large price change. Therefore, we create a control sample of stocks that also experience a large price change, but did not hit their limit. By looking at pre- to post-hit period changes within each stock group, and by comparing these changes across the two stock groups, we can better identify the impacts of price limits. Specifically, we find that price limits (1) do not improve information asymmetry, (2) delays the arrival of information, and (3) cause order imbalances prior to and after a limit-hit.

In conclusion, our results reveal that even in a market with a wide price limit band, price limits do not improve market efficiency, but impose serious costs. Recently, the Stock Exchange of Thailand expanded their price limits from 10 percent to 30 percent, but the Taiwan Stock Exchange narrowed their price limits from 7 percent to 3.5 percent. However, based on prior research and our own empirical study, trying to identify the optimal price limit level may be a futile task. Instead, policy makers may wish to consider eliminating these price limit mechanisms.

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Table 1
Sample Sizes

Two sets of stocks have been identified. Limit-hit group (LHG) contains 98 stocks that hit the 30%-limit during a particular trading session whereas no-hit group (NHG) contains 175 stocks that experience a price change of at least 15% but less than 30% of the previous session closing price. This table presents the number of cases in each of the two sample groups during the study period, 1995-1996, tabulated by board, year and trading session. Main Board stocks are more established firms including blue chip firms while Second Board stocks are younger and smaller in market capitalization. Sessions M and A stand for morning (9:30 a.m. to 12:30 p.m.) and afternoon (2:30 p.m. to 5:00 p.m.) trading sessions, respectively.

Sample	**Limit-Hit Group (LHG)**								**No-Hit Group (NHG)**							
Board	Main Board				Second Board				Main Board				Second Board			
Year	1995		1996		1995		1996		1995		1996		1995		1996	
Session	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A
Number of Cases	2	3	21	5	2	2	44	19	1	0	41	12	4	4	86	27
Sub-total	98								175							

Table 2
Descriptive Statistics

This table provides summary statistics on session trading volume, trading value, trade frequency, trading volume and value per trade, the session turnover ratio and market capitalization for two groups: limit-hit group (LHG) and no-hit group (NHG). The session turnover ratio is computed by using the trading volume (in shares) during Session S_0 (the event session) divided by the total number of shares outstanding for the stock. The market capitalization is the product of the number of shares outstanding and the year-end share price.

	Mean	Standard deviation	Max	Median	Min
Panel A: Limit-Hit Group (LHG) (n=98 stocks)					
Trading volume (in 1,000 shares)	3,502	5,707	33,004	1,565	57
Trading value (in RM million)	32.62	44.85	257.72	17.17	0.56
Trade frequency (in number of trades)	1,302	1,386	7,314	892	56
Trading volume per trade (in shares)	2,177	1,271	9,636	1,818	517
Trading value per trade (in RM)	25,963	24,505	192,845	19,306	3,008
Turnover ratio	0.0832	0.0855	0.4283	0.0590	0.0014
Capitalization (in RM million)	525	628	3,532	271	74
Panel B: No-Hit Group (NHG) (n=175 stocks)					
Trading volume (in 1,000 shares)	1,509	1,854	13,643	957	51
Trading value (in RM 1 million)	14.40	16.72	111.60	8.48	0.86
Trade frequency (in number of trades)	684	558	3700	514	102
Trading volume per trade (in shares)	1,979	948	8,977	1,790	418
Trading value per trade (in RM)	20,474	15,993	109,928	15,444	5,373
Turnover ratio	0.0517	0.0528	0.3275	0.0336	0.0007
Capitalization (in RM million)	426	511	3,582	268	81

Table 3
Duration of Limit-Halt

Summarized in this table is the duration of the limit-halt as measured from the first limit-hit occurrence until the last moment when the price still remains at the limit (i.e., prior to the emergence of a new price) for the 98 Limit-Hit Group (LHG) stocks. The summary statistics are reported by trading sessions.

	Sample Size	Mean (minutes)	Standard Deviation (minutes)	Minimum (minutes)	Median (minutes)	Maximum (minutes)
Total Sample	98	63.16	60.30	0.20	40.09	178.88
Morning Session	69	70.99	62.21	0.33	54.75	178.88
Afternoon Session	29	44.53	51.82	0.20	14.65	146.48

Table 4
Information Asymmetry: Regression Results

Summarized in this table are the results of the following regression:

$$\Delta SYMM_j = \alpha_0 + \alpha_1 \cdot LHG_j + \alpha_2 \cdot BOARD_j + \alpha_3 \cdot YEAR_j + \alpha_4 \cdot SESSION_j + \alpha_5 \cdot TURNOVER_j + \alpha_6 \cdot SIZE_j + \alpha_7 \cdot DURATION_j + \eta_j,$$

where $\Delta SYMM_j$ denotes the change in the degree of information asymmetry from the pre- to post-halt-period, LHG, BOARD, YEAR, and SESSION are indicator variables which take the value of 1 if the stock belongs to the limit-hit group, if the stock belongs to the second board, if the year is 1996, and if the trading session is the afternoon session, and 0 otherwise. TURNOVER is defined as the combined trading volume (in number of shares) in the pre- and post-halt-periods divided by the total shares outstanding. SIZE represents firm size and is defined as the natural logarithm of year-end market capitalization. DURATION is the natural logarithm of the duration of limit-halt in minutes from the first limit-hit occurrence until the last moment when the price still stays at the limit. Parameter coeffiecient estimates and heteroscedastic-consistent t-statistics are reported. Statistical significance at the 5% level is denoted by **.

A. Summary Statistics of ΔSYMM	**Mean**	**Median**
LHG Stocks	0.0703	0.0491
NHG Stocks	0.0569	0.0286

B. Regression Results	**Coefficients**	**t-statistics**
Intercept	-1.0615	-1.364
LHG	0.0191	0.510
BOARD	0.0673	1.285
YEAR	-0.0158	-0.245
SESSION	-0.0715	-2.152**
TURNOVER	-0.2387	-1.109
SIZE	0.0573	1.480
DURATION	-0.0008	-0.100
R^2	0.0317	
F-statistics	1.122	
N	248	

Table 5
Arrival Rate of Informed Traders: Regression Results

Summarized in this table are the results of the following regression:

$$\Delta ARIV_j = \alpha_0 + \alpha_1 \cdot LHG_j + \alpha_2 \cdot BOARD_j + \alpha_3 \cdot YEAR_j + \alpha_4 \cdot SESSION_j + \alpha_5 \cdot TURNOVER_j + \alpha_6 \cdot SIZE_j + \alpha_7 \cdot DURATION_j + \eta_j,$$

where $\Delta ARIV_j$ denotes the change in the arrival rate of informed traders from the pre- to post-halt-period, LHG, BOARD, YEAR, and SESSION are indicator variables which take the value of 1 if the stock belongs to the limit-hit group, if the stock belongs to the second board, if the year is 1996, and if the trading session is the afternoon session, and 0 otherwise. TURNOVER is defined as the combined trading volume (in number of shares) in the pre- and post-halt-periods divided by the total shares outstanding. SIZE represents firm size and is defined as the natural logarithm of year-end market capitalization. DURATION is the natural logarithm of the duration of limit-halt in minutes from the first limit-hit occurrence until the last moment when the price still stays at the limit. Sample sizes vary due to missing observations. Parameter coeffiecient estimates and heteroscedastic-consistent t-statistics are reported. Statistical significance at the 5% level is denoted by **.

A. Summary Statistics of ΔARIV	**Mean**	**Median**
LHG Stocks	0.1604	0.2340
NHG Stocks	-0.0670	-0.2248

B. Regression Results	**Coefficients**	**t-statistics**
Intercept	1.0879	0.458
LHG	0.2386	1.985**
BOARD	-0.2403	-1.382
YEAR	-0.1717	-0.707
SESSION	0.0498	0.332
TURNOVER	-0.4852	-0.469
SIZE	-0.0473	-0.387
DURATION	0.0361	1.015
R^2	0.0295	
F-statistics	0.994	
N	237	

Table 6
Order Imbalance: Regression Results

Summarized in this table are the results of the following regression:

$$\Delta IMBAL_j = \alpha_0 + \alpha_1 \cdot LHG_j + \alpha_2 \cdot BOARD_j + \alpha_3 \cdot YEAR_j + \alpha_4 \cdot SESSION_j + \alpha_5 \cdot TURNOVER_j + \alpha_6 \cdot SIZE_j + \alpha_7 \cdot DURATION_j + \eta_j,$$

where $\Delta IMBAL_j$ denotes the change in order imbalance from the pre- to post-halt-period, LHG, BOARD, YEAR, and SESSION are indicator variables which take the value of 1 if the stock belongs to the limit-hit group, if the stock belongs to the second board, if the year is 1996, and if the trading session is the afternoon session, and 0 otherwise. TURNOVER is defined as the combined trading volume (in number of shares) in the pre- and post-halt-periods divided by the total shares outstanding. SIZE represents firm size and is defined as the natural logarithm of year-end market capitalization. DURATION is the natural logarithm of the duration of limit-halt in minutes from the first limit-hit occurrence until the last moment when the price still stays at the limit. Sample sizes vary due to missing observations. Parameter coeffiecient estimates and heteroscedastic-consistent t-statistics are reported. Statistical significance at the 1% level is denoted by ***.

A. Summary Statistics of ΔIMBAL	**Mean**	**Median**
LHG Stocks	-0.1622	-0.1622
NHG Stocks	-0.0836	-0.1140

B. Regression Results	**Coefficients**	**t-statistics**
Intercept	-0.1896	-0.346
LHG	-0.1050	-3.662***
BOARD	0.0263	0.640
YEAR	-0.0011	-0.019
SESSION	0.1659	5.080***
TURNOVER	0.8389	4.302***
SIZE	0.0025	0.100
DURATION	-0.0141	-1.520
R^2	0.1703	
F-statistics	7.565***	
N	266	