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Lower Tick Sizes and Futures Pricing Efficiency: Evidence from the Emerging Malaysian Market

Abstract

We provide robust evidence of the impact on spot market liquidity and the pricing efficiency of FBM-FKLI index futures following the introduction of lower tick sizes for the stocks listed in the Bursa Malaysia. Our findings show a significant increase in unexpected trading volume and the speed of mean reversion of the futures mispricing. We find that the increase in the unexpected trading volume of the underlying stocks helps in reducing inter-market price discrepancies. The findings offer new evidence that lowering of tick sizes improves pricing efficiency in the Malaysian futures market.

Keywords: Index futures, speed of adjustment, mean reversion, market microstructure, emerging markets.

JEL Classifications: E13, E14

Lower Tick Sizes and Futures Pricing Efficiency:

Evidence from the Emerging Malaysian Market

1. Introduction

In response to the Asian Financial Crisis in 1997, the Malaysian Securities Commission officially implemented a 10-year plan known as the Capital Market Master Plan (CMP) in February 2001. The aim of the CMP was to ensure that in view of the rapidly changing domestic and international environment, investors continue to have access to a fair, efficient and robust securities market. The decision to formulate the CMP was also motivated by the need to identify key areas for market development as part of the orderly and effective deregulation and liberalisation of the Malaysian capital market. One of the key recommendations in the CMP was to reduce the tick sizes for all stocks trading in the Bursa Malaysia with an aim to enhance its competitiveness. Consequently, the tick sizes for all stocks were reduced on 3rdAugust 2009.

The tick size is the minimum price variation that can occur for tradeable assets such as stocks. The tick size therefore is a factor in the determination of the price at which investors are able to execute their trades. During the past decade, many exchanges around the world have reduced tick sizes and there are a number of studies which have investigated the impact of these changes. However, there are relatively few studies which have considered the impact of tick size reduction on the pricing efficiency of futures in the context of emerging markets. This paper examines the pricing efficiency of FBM-FKLI[1] index futures following the tick size reduction in the emerging Malaysian stock market.

Our study differs from the extant literature in the following ways. First, while most previous studies on pricing efficiency have been done in hybrid[2] markets, this paper investigates the impact of tick size reduction in the Malaysian emerging market which is a purely order driven market. This is particularly important since Harris (1997) suggests that, due to the price-time priority rule in a pure order-driven market, the tick size reduction may have much larger impacts on market liquidity.[3] Second, unlike Chen, Chou and Chung (2009), this study considers the impact of tick size reduction on the unexpected spot trading volume, which allows us to glean the source of information arrival in the spot market. Finally, we contribute to the literature on futures' pricing

[1] FBM-FKLI is the code name for the index futures contract. Its value is derived from FBM-KLCI stock index which tracks the performance of the 30 constituent stocks with the largest market capitalisation.

[2] Hybrid-driven markets comprise both quote and order driven markets.

[3] In order driven markets the risk of non-execution of trades increases since it is easier for traders to front-run the *queue* in the limit order book. As a consequence, traders are more reluctant to submit limit orders. Thus, the impact of tick size reduction may be larger due to the fact that limit orders are the primary source of liquidity in a pure order-driven market like Malaysia.

efficiency by investigating the lead-lag relationship between the futures and spot market and their speeds of adjustment which shows how quickly the futures' mispricing is eliminated. Further, our examination also considers the possible impact of the introduction of Exchange Traded Funds (ETFs) in the Malaysian market in 2007 on the pricing efficiency of the futures market.[4]

We report several interesting findings. Our evidence suggests that following the tick size reduction, there is a significant increase in unexpected trading volume of the underlying stocks which helps in reducing the inter-market price discrepancies. There is an improvement in the speed of mean reversion of the futures' mispricing after the introduction of ETFs and it is even higher after the tick size reduction. This suggests that lower tick sizes have a significant positive impact on the index futures' pricing efficiency. Further, the speed at which the stock index reverts to its equilibrium price significantly improves, which suggests that stock specific information is quickly reflected in the spot prices. Overall, our findings show that the effectiveness of index futures as a price-discovery and price-setting mechanism is enhanced following the reduction in tick sizes in the emerging Malaysian market.

The remainder of the paper is organised as follows. The next section presents a review of the relevant literature. Section three explains the data and methodology used and in section four the results are presented and discussed. Section 5 concludes the paper.

2. Literature Review

Verousis, Perotti and Serampinis (2018) review the existing literature on the implications of tick size reduction and show that there is a large body of empirical literature that documents a decrease in transaction costs and an increase in market liquidity following a reduction in the minimum tick size. They also show that a smaller tick enhances the price discovery process. Empirical research has shown that the linkage between spot and the futures markets is facilitated by arbitrageurs (MacKinlay & Ramaswamy, 1988). It is argued that lower tick sizes favour arbitrageurs as their trading costs are reduced. Proponents of lower tick sizes posit that lower trading costs decrease mispricing and facilitate arbitrage trades which, in turn, improve the pricing efficiency of the futures market (see for example, Roll, Schwartz & Subrahmanyam, 2007). Beaulieu et al. (2003) examine the impact of a reduction in tick sizes on price discovery for the Toronto Stock Exchange. They show that spot prices lead the index futures following a reduction in tick sizes. In particular, spot prices can lead the futures

[4] This is particularly relevant since empirical evidence suggests that ETFs facilitate arbitrageurs in executing short arbitrage strategies (see for example, Kurov and Lasser 2002; Park and Switzer 1995; Switzer, Varson and Samia 2000).

price series when the tick size leads to the spot market being more efficiently/speedily priced than the futures market (Beaulieu et al., 2003). However, there can be feedback effects into the futures pricing efficiency via arbitraging activities. The futures relative pricing model itself is based upon such arbitrage activities/justifications (Ross et al., 2007).

On the contrary, opponents argue that lower tick sizes on the underlying stocks may not increase the pricing efficiency of futures since the cost of providing liquidity increases, which adversely affects the profitability of liquidity suppliers (MacKinnon & Nemiroff, 2004). Bacidore (1997) suggests that lower tick sizes reduce both trading costs as well as market depth. If market depth declines there will be a lowering of liquidity which consequently increases futures mispricing. Thus, empirical evidence on the impact of lower tick sizes on stock market trading volume is not conclusive. Further, most studies provide evidence of changes in the expected trading volume. Cummings and Frino (2011) argue that unlike the expected trading volume, changes in the unexpected trading volume capture arbitrage trades which can widen inter market discrepancies. Accordingly, in this study, we focus on the changes in the unexpected spot trading volume.

In an efficient and frictionless capital market there should be no price discrepancy between index futures and its underlying stock index arising from differential information processing across the markets. However, markets are not without friction and thus such inter-market pricing discrepancies between index futures and its underlying stock index do exist (see for example, Brenner, Subrahmanyam and Uno 1989; Puttonen 1993; Yadav and Pope 1994). One of the main reasons for the pricing discrepancies is lack of liquidity in the underlying market. Butterworth and Holmes (2000) suggest that the mispricing observed for the newly introduced FTSE mid-250 futures is due to the relatively less liquid constituent stocks. This suggests that the mispricing arising from inter-market price discrepancies could be minimised by improving the liquidity in the underlying market (Cummings & Frino, 2011).

Existing empirical evidence on the impact of tick size reduction on liquidity provides a mixed picture. On the one hand, previous research shows that a lowering of tick sizes reduces trading costs which positively affects market liquidity. For the Singapore stock exchange, Lau and McInish (1995) find that the move to reduce the tick size on 18 July 1994 for stocks trading above $25 led to reduced bid-ask spreads. Bacidore (1997) reports that following the move to a decimal system of quotation in the Toronto Stock Exchange, there was a significant decline in the average trading costs. Further, Boellen and Whaley (1998) also find that the average bid-ask spreads fall by 21.26% while the daily average trading volume shows an increase of 5.86%, in the NYSE following the switch to one-sixteenths on 27 June 1997. Ronen and Weaver (2001), report similar results for the

AMEX following a reduction in the tick size from $\$1/8$ to $\$1/16$ for all stocks priced over $1. For the Thai stock exchange, Pavabutr and Prangwattananon (2009) report a fall in bid-ask spreads and an increase in the daily average trading volume, especially for high value stocks after tick sizes were reduced on 5 November 2001. In a recent study, Lepone and Wong (2017) show that for the Singapore Exchange, bid-ask spreads decline after a tick size reduction. On the other hand, Bourghelle and Declerck (2004) find that for the Paris Bourse, a reduction in tick size does not necessarily lead to reduced execution costs, but it changes the level of transparency in the liquidity supply. Gwilym et al. (2005) too find that the reduced tick size leads to increases in bid-ask spreads in the UK Gilt futures market. Kurov and Zabotina (2005) examine the impact of the minimum tick sizes on the bid-ask spreads in the E-mini S&P 500 and E-mini Nasdaq-100 futures markets. They show that the tick sizes of the E-mini contracts act as binding constraints on the bid-ask spreads by not allowing the spreads to decline to competitive levels, thereby reducing the incentive for market makers to provide liquidity. Further, as suggested by Jones & Lipson (2001), lower trading costs may adversely affect the market depth, and consequently the liquidity, as lower spreads increase the risk of front-running. Thus the impact of tick size reduction on trading volume is not straightforward and depends on how the demand and supply of liquidity are affected by lower trading costs.

Extant research also provides empirical evidence on the impact of lower tick sizes on pricing efficiency. Beaulieu et al. (2003) investigate the price discovery role of futures contracts on the Toronto Stock Exchange and show that small tick-sizes lead to increased price discovery. Henker and Martens (2005), provide evidence of a reduction in the inter market discrepancies between S&P 500 index futures and its underlying due to a significant increase in the number of arbitrage trades following the introduction of the lower tick sizes in the NYSE. Further, Chordia, Roll, and Subrahmanyam (2008) show that the increased liquidity after the tick size reductions in the NYSE is due to quicker incorporation of firm specific information in the market. Kurov (2008) examines the effect of a reduction in the minimum tick size on execution costs, price discovery, and informational efficiency in the regular and E-mini Nasdaq-100 futures markets. He reports a significant improvement in execution quality and informational efficiency of the E-mini Nasdaq-100 market after the tick size reduction. Hsieh, Chuang, and Lin (2008) show that tick-size reduction in the order-driven Taiwanese Stock Market increase market efficiency and reduce the investors' trading costs. Chen and Gau (2009) examine the competition in price discovery among stock index, index futures, and index options in Taiwan. They show that a smaller tick size induces more informed trading in the stock market, and increases the rate of price-discovery in the stock index and the tracker fund. Chung and Hrazdil (2010) also find improvements in market efficiency following tick size reductions due to increased liquidity in the NASDAQ market.

In contrast to Chen et al., (2009), our results show that the unexpected trading volume after the tick reduction represents trades that serves to narrow the mispricing, an indication that traders are able to incorporate information effectively (Chordia, Roll and Subrahmanyam, 2008) and respond to mispricing more quickly (Henker and Martens, 2005). In other words, the ability to trade the underlying reduces mispricing (Alexander, 2008). Bursa Malaysia uses tick sizes that increase with share prices in a stepwise fashion. The implication is that, even higher priced stocks are most likely be constrained by the size of the tick. Therefore, the constituent stocks that make-up the stock index may experience greater reductions in spreads as these stocks are trading at higher prices and are large (Chung, Kim and Kitsabunnarat, 2005). Further, traders in Bursa Malaysia do not usually quote larger depths for stocks with larger tick sizes (Chung et al., 2005). This implies that the adverse impact on market depth is minimal and hence on arbitrageurs' willingness to trade. The above two reasons explain the higher trading volume following the tick reduction observed in our study, which improves pricing efficiency. Further, the impact of tick size reduction seems inevitable, especially in a relatively less liquid emerging market where the liquidity might be strongly affected (Bekaert, Harvey and Lundblad, 2007). Alternatively, it could be inferred that the lower tick sizes do not cause speculators' trades to exceed those of arbitrageurs' in the composition of the unexpected trading volume (Cummings and Frino, 2011).

Further, even if arbitrageurs are not adversely affected by the tick size reduction, there are two other possibilities why the inter-market discrepancies may increase. First, if index futures are mispriced relative to the underlying, there is a possibility that speculators may use this signal by trading in the constituent stocks due to lower bid-ask spreads instead of trading in the futures market. As a consequence, inter-market pricing discrepancies may widen if speculators' trades exceed those of arbitrageurs' trades. Second, the deviation from the no-arbitrage relationship may be further magnified by the possibility of traders with stock specific information trading more often and thereby attracting new speculators, given the lower trading cost (Boellen & Whaley, 1998). This is particularly so for stocks with higher market capitalisations where speculators are able to act on stock specific information (Sutcliffe, 2006). Thus, the available evidence shows that a lower tick size influences the pricing efficiency through different channels and its impact can differ depending on the market microstructure.

In the context of the Malaysian emerging market, there is only one previous study that has investigated the relationship between tick sizes and liquidity. Chung, Kim and Kitsabunnarat (2005) show that the larger tick sizes impose a significant binding constraint on stocks listed in the Bursa Malaysia. They find that the average bid-ask spread increases from 1.79% to 1.90% when the stocks move to a higher tick category and decreases from 1.98% to 1.94% when the stocks move to a lower tick size category.[5] However, they do not examine the channels of this impact. The positive effect of lower tick sizes on liquidity and pricing efficiency is conditional on whether the unexpected trading volume, which represents trades by arbitrageurs, increases.

There are two components of unexpected spot trading volume. One represents those of arbitrageurs which narrow down inter-market price discrepancies, and the other represents those of speculators which widen these price discrepancies. For the pricing efficiency to improve, a reduction of tick sizes should increase the unexpected trading volume in the underlying spot market. Cummings and Frino (2011) suggest that it should be possible to glean the source of information arrival in the spot market by assessing the impact of the unexpected trading volume on the mispricing.

While the impact of tick size reduction on pricing efficiency remains a point of academic debate, there is an agreement that the introduction of exchange-traded funds (ETFs) has positive effects. Park and Switzer (1995) find that the Toronto 35 index futures price conforms to the theoretical value of the Toronto 35 index much better after the introduction of TIPs. Switzer, Varson and Samia (2000) and Chu and Hsieh (2002) investigate the impact of the introduction of SPDRs. Both conclude that the introduction of the SPDRs improve the S&P 500 index futures' pricing efficiency. Their results provide support for the notion that ETFs facilitate arbitrage trades. Kurov and Lasser (2002) find that the introduction NASDAQ-100 Index Tracking Stocks (QQQs) facilitates spot-futures arbitrage and, in turn, improves the pricing efficiency of the futures index.

Concerning Bursa Malaysia, FBM-KLCI exchange traded funds (ETFs) were first listed on 19 July 2007. Given that the tick size reduction is also effective on the exchange-traded funds, the pricing efficiency of FBM-FKLI index futures should improve, since lower tick sizes should encourage more trading. The extant literature has shown that ETFs facilitate arbitrageurs in executing the cash-legs for both long and short arbitrage strategies. Further, Chung et al., (2005) show that, since traders in Bursa Malaysia do not quote higher market depth for stocks with higher tick size, the adverse impact of the tick size reduction on the ability and willingness of arbitrageurs in initiating trades is minimal. It is, therefore, expected that both the introduction of ETFs and lower tick sizes should improve the liquidity and pricing efficiency of the emerging Malaysian futures market.

[5] The binding constraint hypothesis predicts that the spread widens (narrows) when stocks move to a larger (smaller) tick category (Harris 1994).

3. Methodology and Data

3.1 Methodology

3.1.1 Theoretical index futures prices

Theoretically, the fair price, i.e. no-arbitrage price of index futures, is given by the cost-of-carry model. Thus, the intrinsic value of the index futures, as implied by the underlying market price, is defined using:

$$F_t^* = S_t e^{(r-d)(T-t)} \tag{1}$$

where S_t is the observed price of the stock index at time t , r is the risk-free interest rate as proxied by the daily 3-month T-Bill rate, d is the actual dividend yield[6] on the stock index portfolio, and $(T-t)$ is the number of days to expiration of index futures contract. From this formula, the futures price will converge to the value of the spot index as the futures contract approaches maturity (that is, the basis converges to zero at expiration). Similar to previous studies, this paper defines mispricing as the difference between the observed futures price and its intrinsic price, deflated by the price of the underlying index at time t as follows:

$$x_{f_t} = \frac{F_t - F_t^*}{S_t} \tag{2}$$

For robustness, our analysis estimates another measure of mispricing implied by the futures market (Roll et al. 2007). It is defined as the difference between the intrinsic spot price[7] and the observed spot index price, deflated by the price of the underlying index, at time t as follows:

$$x_{S_t} = \frac{F_t e^{-(r-d)(T-t)} - S_t}{S_t} \tag{3}$$

The index futures are considered to be efficiently priced if there is no mispricing i.e. $x_{f_t} = x_{s_t} = 0$. Mispricing can be either positive or negative and hence absolute values for both measures defined at equations (2) and (3) are considered.

3.1.2 Mean reversion

The mean reversion properties of the mispricing x_{s_t}, as defined in equations (2) and (3), are examined to establish whether the speed of mean reversion is faster after the reduction in tick size. Following, Brennan and Schwartz's (1990) Brownian bridge process for the mispricing, we estimate the speed of mean reversion using:

$$db(t) = -\frac{\mu b}{\tau} dt + \omega dz \tag{4}$$

[6] Switzer et al., (2000) have shown that failure to use the actual dividend of the constituent stocks that make-up the index could lead to measurement error in the cost-of-carry model. Thus, it is important to obtain the actual dividend yield in calculating the index futures intrinsic value.

[7] The intrinsic stock index price is calculated by discounting the observed price of the nearby index futures contract.

where $b(t)$ represents the signed mispricing at time t , τ is the time to maturity, μ is the speed of mean reversion. ω is the instantaneous standard deviation of the process and d the differential operator. The maximum likelihood estimator is used to estimate the parameters μ and ω . The log likelihood function of the parameters is

$$lnL(\mu,\omega) = -\frac{T}{2}ln2\pi - \sum_{t-1}^{T} ln\theta_t - \frac{1}{2}\sum_{t=1}^{T}\frac{\mu_t^2}{\theta_t^2} \quad (5)$$

where

$$\mu_t = b(t+1) - (1-\frac{1}{T-1})^{\mu} b(t) \quad (6)$$

and

$$\theta_t^2 = \frac{\omega^2(T-t-1)}{2\mu-1}[1-(1-\frac{1}{T-t})^{2\mu-1}] \quad (7)$$

The parameters are estimated in the standard fashion by maximising equation (5).

3.1.3 Impact of tick size reduction on stock market trading volume

Following Chordia, Roll and Subrahmanyam (2001), our study employs the following model to examine the impact of a reduction of tick sizes on the stock market trading volume[8].

$$\Delta V_t = \alpha + \beta_1\Delta SR_t + \beta_2\Delta TS_t + \beta_3\Delta QS_t + \beta_4\Delta MKT_t + \beta_5|\Delta P_t| + \sum_{i=1}^{n}\varphi_i\Delta V_{t-i} + \sum_{j=1}^{4}\delta_i d_j + \beta_6 tick_t + \varepsilon_t \quad (8)$$

Specifically, six explanatory variables are used to explain daily changes in trading volume, ΔV_t . These include interest rates, an equity market performance indicator, market volatility, momentum effect, dummies for day of the week and the dummy for tick size reduction. The rationales for selecting these variables are reported below.

Interest rates: ΔSR_t , ΔTS_t and ΔQS_t are the daily changes in short-term rates, term spread and quality spread, respectively. A decline in short-term rates reduces the cost of holding the inventory of stocks and the cost of margin trading. As a result, demand and supply of equities increases. Increases in the term spread indicate a positive market outlook, which may influence investors to reallocate their wealth between equity and bonds to maximise their performance. Trading activities may increase as a result. An increase in the quality spread implies a higher perceived risk of holding an inventory of stocks and thereby a decline in the liquidity.

[8]The model is fitted using an ARIMA (10, 0, 0) model to account for the momentum effect and autocorrelation. Due to the presence of ARCH effects, a GARCH (1,1) model is fitted to account for the conditional variance. Modelling diagnostics indicate that the residuals from the estimated model follow a white noise process (results not reported but can be made available on request).

The proxy for short-term rates (SR) is the daily KLIBOR[9] overnight rate. The term spread (TS) is defined as the daily difference between KLIBOR overnight rates and the 10-year Malaysian Government Securities (MGS)[10] yield. The quality spread variable (QS) is defined as the daily difference between the yield on Bank Negara Malaysia's (BNM) AAA 10-year Private Debt Securities (PDS)[11] and 10-year MGS yield.

Equity market performance: MKT is a dummy variable to proxy for concurrent equity market performance, which takes the value 1 if the concurrent spot index return is positive, and zero otherwise. This dummy variable is included because recent price movements may affect investors' perceptions on the outlook for the market, which, in turn, may influence their portfolio composition. Moreover, directions of price movements may have asymmetric effects on the trading volume because market makers may find it challenging to adjust their inventories in response to a falling market. The signed concurrent daily FBM-KLCI stock index return is used as a proxy for recent market performance. Appendix A reports summary statistics for the debt and equity market variables illustrated above.

Market volatility: $|\Delta P_t|$ is the absolute change in the spot index price, which is considered as the proxy for stock market volatility (Chordia et al. 2001). Numerous studies report a positive relationship between volume changes and absolute price changes, both in equity and futures markets (see, Karpoff 1987). This implies that large increases in trading volume may be associated with either a large increase or a large decrease in prices of the constituents stocks. Sudden increases or decreases in prices represent risks of trading in the equity markets, which may deter traders from trading during periods of high stock market volatility (Foster and Viswanathan 1990). The absolute price change of the spot returns, $|\Delta P_t|$ is used as a proxy for market volatility.

Momentum effect: The momentum effect implies that changes in today's trading volume are associated with yesterday's trading volume changes. Thus, to account for momentum effect, we include, ΔV_{t-i} where "$\boldsymbol{i}$" accounts for the number of lag(s) of daily trading volume. Our model includes 10 lags of daily changes in trading volume based on the Akaike Information Criterion (AIC).

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[9]The Kuala Lumpur Interbank Offered Rate (KLIBOR) is the average interest rate at which term deposits are offered between prime banks in the Malaysian wholesale money market.

[10]MGS are coupon-bearing, long-term bonds issued by the Malaysian Government which are the most actively traded government securities.

[11]PDS are issued by corporations under conventional or Islamic principles. PDS can be commercial papers (CPs), medium term notes (MTNs), bonds, asset-backed securities (ABS), amongst others.

Day of the week: Following Chordia et al. (2001), dummy d_j is used to capture the effect of daily variations in trading volume. These dummy variables are included in our model to access whether the day of the week effect on trading volume exists in the Malaysian market.[12]

Tick size reduction: reduction in the tick size is captured via a dummy variable that equals 1 following the implementation of tick size reduction (3 August 2009 to 31 Dec 2012). A significant positive coefficient is expected indicating that the tick size reduction leads to an increase in trading volume.

3.1.4 Impact of trading volume and tick size on mispricing

Similar to Cummings and Frino (2011), we estimate the following equation to examine the effect of the reduction in tick sizes and the effect of unexpected trading volumes of stock index and index futures on the futures mispricing;

$$|x_{f_t}| = \beta_0 + \beta_1 tick + \beta_2 etf + \beta_3 crisis + \beta_4 V_t^{futures} + \beta_5 V_t^{spot} + \beta_6 Vol_t^{futures} + \beta_7 (V_t^{spot} * tick) + \beta_8 (V_t^{futures} * tick) + \sum_{i=1}^{p} \varphi |x_{f_{t-i}}| + \sum_{j=1}^{q} e_{t-j} + e_t \quad (9)$$

where, $|x_{f_t}|$ is the daily absolute mispricing defined in equation (2). $tick$, etf and $crisis$ are dummy variables. $tick$ equals 1 for the period following the implementation of the tick size reduction. A significant negative coefficient of the $tick$ dummy will indicate that the reduction in tick sizes significantly lowers the daily average absolute mispricing. etf equals 1 for the period from 19 July 2007 to 31 December 2012. A significant negative coefficient of the dummy would suggest that introduction of ETFs reduces futures mispricing.

During periods of high uncertainty, and hence volatility, it is more likely for asset prices to temporarily deviate from their equilibrium prices. Hence, the $crisis$ dummy is included in the model as a control variable. The period characterised by the global financial crisis period spans from 16 January 2008 to 10 March 2009 and so the $crisis$ dummy takes value of 1 during this period and 0 otherwise.

$V_t^{futures}$ and V_t^{spot} represent the unexpected futures volume and unexpected spot volume respectively. Both series were decomposed using a similar procedure to that employed by Bessembinder and Seguin (1992). Specifically, 100-day moving averages for both trading volume series are generated.[13] Next, the raw trading volume series are de-trended by deducting the 100-day moving averages. Finally, the de-trended series are

[12] We are unaware of any studies that have examined day of the week effect on volume in the Malaysian market. Brooks and Persand (2001) find significant positive Monday average returns and significant negative Tuesday returns in the Malaysian market.

[13] The 100-day moving average series captures minor adjustments to changes in the anticipated trading volume.

decomposed into expected and unexpected components using an ARIMA specification. In particular, ARIMA (1, 0, 3) was used for the spot volume and ARIMA (1, 0, 7) was used for the futures volume. The sum of constant and predicted residual represents the unexpected volume. A significant negative coefficient would indicate that the unexpected volume represents trades by the arbitrageurs that facilitate quicker incorporation of stock specific information which help in reducing mispricing.

$(V_t^{spot} * tick)$ and $(V_t^{futures} * tick)$ captures the interaction effect between the unexpected component of spot trading volume, V_t^{spot} , futures trading volume, $V_t^{futures}$ and tick size dummy, respectively. Significant negative coefficients would suggest that traders are able to incorporate stock specific information and respond faster to deviations from the no-arbitrage relationship as a result of lower tick sizes.

$Vol_t^{futures}$ is index futures volatility defined as $Vol_t^{futures} = |\log(F_t) - \log(F_{t-1})|\sqrt{\pi}/2$, similar to Bessembinder and Seguin (1992). The variable is included in the model to control for daily movements in the futures market. Given the inherent advantages of trading the index futures contract, index futures are more volatile which may have a significant impact on index futures pricing efficiency.

Diagnostic tests (results not reported for brevity but can be made available on request) indicate that the correlations between the volatility of FBM-FKLI index futures, the unexpected volume of FBM-KLCI stock index and the unexpected volume of FBM-FKLI index futures are minimal such that they do not have any significant effects on the standard errors of the regression estimates. An AR (6) model is fitted with a GARCH (1, 1) process for estimating conditional variance. Additionally, for robustness, we re-estimate equation (9) using $|x_{s_t}|$ as defined in equation (3), the mispricing implied by the index futures as the dependent variable. An ARMA (2, 2) model is fitted with a GARCH (1, 1) process for the conditional variance.

The absolute mispricing series, as defined in equation (2) and (3), are further investigated by using OLS and quantile regressions which allows us to observe how the independent variables affect mispricing at various quantiles (θ) using the bootstrapping method.

3.1.5 The lead-lag relationship and the speed of adjustment

We examine the temporal causality between futures and spot returns using the following cross-correlation function:

$$\rho_{yx}(k) = \frac{E\{(y_t-\mu_t)(x_{t-k}-\mu_x)\}}{\sigma_y\sigma_x} \quad (10)$$

where y and x represent the returns of futures and spot, respectively. k represents the number of leading or lagging periods. $k = 0$ there is no lead lag relationship, whereas if k is positive it would indicate that futures returns lead spot returns and vice versa.

Our analysis employs Amihud and Mendelson's (1987) partial adjustment model to further investigate the lead-lag relationship between stock index and index futures. While, VECM models have been used and do provide an alternative methodology, the advantage of the speed of adjustment approach is that it does provide a readily interpretable metric for relative adjustments in that speeds of adjustment greater than (less than) one indicates over (under) reactions. Furthermore, they provide the means of adjusting for thin trading effects.

In the absence of thin trading, the speed of adjustment factor of spot returns, g_s, is measured by the following estimator (Theobald & Yallup, 1998)

$$cov\{r_{f_{t-1}}, r_{s_t}\} = (1 - g_s)[cov\{r_{f_t}, r_{s_t}\}] \tag{11}$$

where,$r_{f_t}$is the return on futures index in period t ; r_{s_t} r_{s_t} denotes the return on spot index and $\mathbf{cov}$ is the covariance operator. The speed of adjustment of futures return, g_f is

$$cov\{r_{s_{t-1}}, r_{f_t}\} = (1 - g_f)[cov\{r_{s_t}, r_{f_t}\}] \tag{12}$$

The partial adjustment coefficient, g_i($\boldsymbol{i}$ = futures return or spot returns) represents the speed at which prices (in natural logarithm), P_{i_t}, adjust or revert to their equilibrium prices, V_{i_t}. It is estimated as

$$P_{i_t} - P_{i_{t-1}} = g_i\{V_{i_t} - P_{i_{t-1}}\} + u_{i_t} \tag{13}$$

where, $u_{i_t}$is an i.i.d. noise term[14]. Amihud and Mendelson (1987) assume that the equilibrium prices follow a logarithmic random walk with drift characterised as follows

$$V_{i,t} = \mu + V_{i,t-1} + v_{i,t} \qquad (\qquad 14)$$

For the spot index return, $g_s < 1$ indicates that futures return, r_{f_t} leads spot return, r_{s_t} . In other words, spot returns do not fully adjust towards equilibrium prices, as per equation (13). However, this relationship is predicated in the absence of thin trading. A similar procedure to that in Theobald and Yallup (2004) is adopted to account for non-synchronous trading. The model provides the flexibility to estimate speed of adjustment directly in the presence of thin trading.

We represent equation (13), after first differencing and rearranging, as

$$R_{i,t} = (1 - g_i)R_{i,t-1} + g_i\Delta V_{i,t} + \Delta u_{i,t} \tag{15}$$

and by substituting for $\Delta V_{i,t}$ from equation (14), equation (15) becomes

[14] $g_i = 1$ corresponds to full adjustment towards equilibrium prices, while $g_i < 1$ and $g_i > 1$ corresponds to under-reaction and over-reaction respectively.

$$R_t = g\mu + (1-g)R_{t-1} + ge_t + u_{i,t} + u_{i,t-1} \quad (16)$$

when non-synchronicities are present equation (16) modifies to

$$R_{m,t} = g\mu + (1-g)R_{m,t-1} + \sum_{i=10}^{q} w_i L^i \{ge_{i-t} + u_{t-i} - u_{t-1-i}\} + (1-(1-g)L)r_t \quad (17)$$

The price adjustment effects manifest themselves within the AR (1) coefficient, which will provide estimates of the speed of adjustment coefficient.

3.2 Data

Daily closing prices for the FBM-KLCI Composite Index and nearby[15] FBM-FKLI index futures contracts traded on the Bursa Malaysia are examined. The sample period is from 2 January 2002 to 31 December 2012, consisting of 2704 daily observations.[16] Daily observations for FBM-KLCI include closing prices of the index, trading volume and dividend yield. Trading volume represents the total value of the constituent shares traded on a particular trading day. Dividend yield is the total actual dividend amount for the index expressed as a percentage of the total market value of the constituent stocks. For FBM-FKLI index futures, daily observations include settlement price, the total number of contracts traded for the day and the number of days to expiration. Settlement price is the price at which a contract is settled at the end of the trading day. The above data including daily KLIBOR overnight rates, 3-month T-bill rates and 10-year Malaysian Government Securities (MGS) yield were obtained from DataStream. The 10-year Private Debt Securities yield is also obtained from Bloomberg.

For investigating the impact of the tick size reduction, the sample is divided into two sub-periods: i) from 2 January 2002 to 2 August 2009 (1864 observations) representing the period before the tick size reduction and ii) from 3 August 2009 to 31 December 2012 (840 observations) representing the period after the tick size reduction.

The returns of the stock index and index futures are defined as $r_{s_t} = 100 * \ln(\frac{S_t}{S_{t-1}})$and $r_{f_t} = 100 * \ln(\frac{F_t}{F_{t-1}})$, respectively. The first differenced series are stationary as confirmed by the Augmented Dickey-Fuller test (not reported but results are available on request).

[15] The extant literature uses nearby contracts (see for example, Pok, Poshakwale & Ford, 2009; Switzer et al., 2000; Theobald & Yallup, 1998).

[16] Despite the fact that the Capital Market Masterplan (CMP) was officially launched in February 2001, the 15 recommendations that directly affect derivatives trading were only implemented from the beginning of January 2002. Thus, we choose 2 January 2002 as the starting date for our sample.

4. Empirical Results

4.1. Descriptive statistics

4.1.1. Trading volume

Table 1 provides summary statistics of daily trading activities for the constituent stocks and the index futures, before and after the reduction of tick sizes as well as for the whole sample period considered in the study. Panel A shows the summary statistics for the value of shares traded in Malaysian Ringgit (RM), while, Panel B shows the summary statistics for the value of futures contracts. The volume of constituent stocks traded is significantly higher in the post-tick period. This suggests that the constituent stocks may have benefitted from the reduction in the tick sizes. Similarly, trading activities are higher in the futures market in the post-tick period, as indicated by the higher total value of contracts traded. Further, the estimates of standard deviation, σ, and coefficient of variation, CV, for both measures of trading activity are lower for the post tick period which indicate that lower tick sizes have a positive impact.

<<Insert Table 1>>

4.1.2. Mispricing

Table 2 reports the descriptive statistics of index futures mispricing for the whole period and for the sub-periods before and after the implementation of lower tick sizes. Panels A and B show the descriptive statistics for mispricing as implied by the stock index, while Panels C and D show the descriptive statistics for mispricing as implied by the index futures.

Panel A shows that the mispricing of the FBM-FKLI is significantly lower (-0.050%) for the post tick period. Similarly, in Panel B the average absolute mispricing (0.297%) is significantly lower for the post tick period compared to the pre-tick period (0.994%). Further, it is interesting to note that the first-order autocorrelation of the changes in mispricing and absolute mispricing are negative throughout the sample period. This provides evidence of mean reversion in the series. The first-order autocorrelation of the mispricing series during the pre-tick period is as high as 0.827, indicating high persistence in mispricing that declines significantly in the post-tick period. The first-order autocorrelation of absolute mispricing indicates similar result. Panels C and D of Table 2 report the descriptive statistics of mispricing and absolute mispricing, calculated using equation (3). The findings indicate that the mispricing and the absolute mispricing is significantly lower for the post-tick period. Similarly, the first-order changes in autocorrelation are negative, indicating significant evidence of mean reversion, discussion of which follows in the next paragraph.

<<Insert Table 2>>

Panel E of Table 2 reports the speed of mean reversion for mispricing as estimated in equation (3). It is interesting to note that estimated speed of mean reversion is significantly higher after the introduction of ETFs. The mean reverts to zero at a greater speed suggesting active arbitrage trading and efficient futures pricing in the post tick period. Overall, the evidence suggests that the introduction of smaller tick sizes seems to have a positive effect on the pricing efficiency of FBM-FKLI index futures.

4.1.3. Returns

Table 3 reports the descriptive statistics of spot index returns (r_{s_t}) and the FBM-FKLI index futures returns (r_{f_t}) for the whole as well as for the two sub-sample periods. The average returns in the spot market (0.034%) are similar to the average futures returns (0.033%). However, the standard deviation (0.796%) of spot return is lower than the standard deviation (1.018%) of futures returns, indicating the higher volatility of the futures market. For the two sub periods too, the standard deviation of spot returns is relatively lower than in the futures. However, it is worth noting that spot and futures returns volatility is higher in the pre-tick period compared to the post-tick period.

It is evident that both returns series are negatively skewed. However, the skewness is lesser for the post-tick size period. Also, the positive kurtosis decreases in the post-tick reduction period. This has significant implications. A reduction in negative skewness with considerable reduction in positive kurtosis indicates a decline in the probability of high negative returns in the post-tick period. Further, for the post-tick period; there is no significant difference in the kurtosis between spot (4.849) and futures (4.669) which suggests that there is less likelihood of abnormal positive or negative spot and futures returns for the period following tick size reduction.

<<Insert Table 3>>

4.2. Regression results

4.2.1. Impact of Tick Size on Trading Volume

Table 4 reports the ARIMA (10, 0, 0)-GARCH (1, 1) estimation of equation (8) for the scaled spot trading volume (in millions of Ringgit). The intercept is significantly negative indicating a considerable decrease in trading volume on Fridays of the week. The day of the week dummies are positive for Tuesday, Wednesday and Thursday, while it is negative for Monday. This suggests that trading volume is lower during the beginning and towards the end of the trading week whereas it is higher during the remaining days of the week. The term-spread and quality-spread have positive coefficient signs and these are only marginally significant. However, both have little influence on trading volume. Consistent with the previous studies, the volatility of spot returns is positively related to the daily change in trading volume. Further, significant coefficients for the lags of trading volume changes suggest the presence of momentum effects. Most importantly, the coefficient of the tick size dummy is positive and statistically significant. This indicates that the reduction in tick sizes positively impacts upon the average trading volume in the emerging Malaysian market.

<<Insert Table 4>>

4.2.2. Impact of Tick Size and Trading Volume on Mispricing

Table 5 reports the coefficient estimates of equation (9). There is evidence of mispricing as reflected by a statistically significant constant term. Results show that the reduction of tick sizes reduces absolute daily mispricing, as the coefficient for the tick dummy is negative and highly significant. The evidence also implies that the reduction of tick sizes strengthens the spot-futures pricing relationship. Further, the introduction of the ETFs seems to improve the pricing efficiency of index futures. As expected, the global financial crisis of 2008 has had an adverse impact on the index futures' pricing efficiency.

The coefficient of futures volatility $Vol_t^{futures}$ is positive and significant which suggests that new information is incorporated with greater speed in the futures market. Significant positive autocorrelation coefficients (up to lag 6) indicate that mispricing is persistent. We note that the coefficients for unexpected volumes V_t^{spot} and $V_t^{futures}$ are positive and significant. This implies that the unexpected component of trading volumes represents trades which widen futures mispricing. However, when inter-acted with the tick size change dummy, the coefficients are negative and statistically significant. This suggests that tick size reduction leads to lower mispricing and the effect is transmitted via an increase in the unexpected trading volume. The evidence suggests the reduction of tick sizes improves the pricing efficiency of index futures.

<<Insert Table 5>>

Tables 6 & 7 report the results of quantile regressions for the absolute mispricing series as defined in equations (2) and (3), respectively. The negatively significant OLS coefficients of the tick dummy indicate lower mispricing after the tick size reduction. For the higher quantile regressions ($\theta > 0.5$), the coefficients of the tick size dummy are again significantly negative, indicating improvements in pricing efficiency after tick size reduction. The results also show that the introduction of ETFs reduce mispricing ($\theta < 0.5$). The quantile regression estimates show that our results are robust and confirm that the reduction of tick sizes has improved the pricing efficiency of the FBM-FKLI index futures in the Malaysian market.

<<<Insert Table 6 & 7 >>

4.2.3. Speed of adjustment

Finally, we provide evidence of the interactions between futures return and spot returns by investigating the lead-lag relationship in terms of speed of adjustment while considering the possible effects of thin trading. We consider five estimators of the speed of adjustment. The estimates are shown in Table 8 for the period before and after the tick size reduction. The first four estimators are derived assuming that the intrinsic values follow a random walk process. The estimators are: i) the co-variance ratio; ii) AR (1); iii) ARMA (1,1); iv) ARMA (1,X) and v) the fifth speed of adjustment estimator assumes a non-random walk process.

The second column of Table 8 reports the cross-covariance estimates of the partial adjustment factor for the futures and the spot markets. The futures seem to adjust to its equilibrium level at a higher speed, i.e. close to unity in comparison to the spot. However, in the post tick period, the spot adjusts to its equilibrium level at a higher speed compared to the period before the tick was reduced. This indicates that post the tick-size reduction, stock specific information is reflected faster in the underlying market.

Columns three to five of Table 8 present the estimates of the speed of adjustment using three estimators based on the ARMA specifications. In general, for the whole sample, the results show that the partial adjustment factor for the index futures contract, g_f, is significantly higher than for the spot, g_s. Further, the results show that adjustment factors that are significantly different from one are more frequently evident in the spot market. This implies that, in general, the underlying market under-reacts to information. The AR (1) specification assumes an absence of spread and noise effects. The findings show that for all the sub-sample periods the index futures incorporate information ahead of the stock index. The estimates based on the ARMA(1,1) specification are calibrated assuming an absence of thin trading effects. The findings indicate that when the noise and spread effects are considered, both futures and spot over-react to information. It is noted that the spot adjusts at a considerably lower rate following the tick size reduction. This implies that the tick size reduction has a dominant impact on the spot market given that tick size reduction directly affects the spread.

The ARMA(1,X) specification takes into account the thin trading effect in the underlying. The estimates for the futures are similar to the ARMA (1, 1) specification. The optimal lag order of moving average (X) is based on Akaike Information Criterion (AIC). In line with the above findings, the result suggests that the reduction in tick sizes facilitates traders in exploiting stock specific information, which strengthens the linkage between stock index and index futures.

In the last two columns of Table 8, we report the model estimates that assume a non-random walk intrinsic value process. The estimates are obtained by using non-linear least squares. Essentially, the intrinsic value process is a random walk when the gamma value is equals to unity, i.e. the model will be the same as the ARMA (1, 1) model. The results indicate that the speeds of adjustment are higher for the futures, similar to those reported previously. In fact, for the futures, it is higher for the whole sample period and in each of the sub-periods. We show that the speeds of adjustment for futures are significantly higher than one (over-reaction) and for the spot are significantly less than one (under-reaction) throughout the whole and for sub-sample periods. This suggests that the speeds of adjustments are sensitive to the specification of the underlying intrinsic value process. In general, the spot under-reacts in relation to intrinsic values, while futures, in most instances, over-react, consistent with its price discovery role.[17] With regard to the coefficients in the intrinsic value process, γ_i, there is no evidence of over-or under-reaction for both futures and spot. In general, futures' speeds of adjustment are higher and closer to unity in comparison to the spot's speed of adjustment towards intrinsic values. Further, it can be established that the intrinsic values for both markets follow a random walk process. The findings show that the partial adjustment factor for the index futures contract, i.e., $g(f)$, and the partial adjustment factor for the stock index, i.e., $g(s)$ are statistically significantly different from one at the 1% level. This suggests that both futures and spot markets reflect less than full price adjustment.

<<Insert Table 8>>>

4.3 Robustness Check

We conduct a cointegration test using the Engle and Granger's (1987) two-step single equation technique, which rejects the null hypothesis of non-stationarity in the residuals. This indicates that there exists a cointegrating relationship between stock and index futures, and thus there is a corresponding vector error correction model (VECM).

Following Wahab & Lashgari (1993), we define the set of VECM as:

[17] Indeed, Choy and Zhang (2010) find that in Hong Kong, the futures market plays a dominant role in price discovery.

$$\Delta S_t = \alpha_1 + \alpha_S \hat{Z}_{t-1} + \sum_{i=1}^{n} \alpha_{11}(i) \Delta S_{t-i} + \sum_{i=1}^{n} \alpha_{12}(i) \Delta F_{t-i} + e_{S_t} \quad (18)$$

$$\Delta F_t = \alpha_1 + \alpha_F \hat{Z}_{t-1} + \sum_{i=1}^{n} \alpha_{21}(i) \Delta S_{t-i} + \sum_{i=1}^{n} \alpha_{22}(i) \Delta F_{t-i} + e_{F_t} \quad (19)$$

where S_t and F_t are spot and futures prices, respectively, and the Δ denotes the first-difference of the variable. The lagged one-period equiblirium error, $\hat{Z}_{t-1}$ measures the speed at which the left-hand variable reverts to its equilibrium level. It also indicates the direction of the causal relationship. For example, if the coefficient for $\hat{Z}_{t-1}$ in the first equation is zero, then S_t does not respond to previous period's adjustment towards long-run equilibrium. The lagged first differences represent short-run effects of the previous period's returns on the current period's returns. If α_S is zero and all $\alpha_{12}(i)$ are zero in the former equation, then ΔF_t does not Granger cause ΔS_t. Using Hannan and Quinn's information criterion (HQIC) we select the autoregressive lag length as four. HQIC statistics is used because it provides consistent estimates of p, the lag length, while AIC statistics tend to overestimate the true lag length (Becketti, 2013). The numbers of lags are similar for both pre-and post-tick size reduction. Diagnostic tests indicate no evidence of instability (examining Eigenvalues of the companion matrix for bivariate VECM), nor there is evidence of autocorrelated errors (examining Lagrange-multiplier test for autocorrelation).

The results of the fitted VECM for pre and post-tick size periods are displayed in the Tables A1 and A2 in the appendix, respectively. For the pre-tick period, Panel B of Table A1 shows that for equation (18) the coefficients of ΔF_{t-i} are positive and significant. This implies that the spot index moves in the direction of the previous movement of the futures price, underlining the price discovery role of the futures market for the spot market. For the post-tick period, Panel B of Table A2, shows that the coefficients of ΔF_{t-i} are insignificant. This indicates that the lead of futures over spot weakens post-tick period. Prior to the tick reduction, error correction mechanism occurs in both futures and spot markets as indicated by the significant coefficient on for both equations. In comparison, it is significant only in the spot returns equation after the tick reduction. This indicates that following the tick reduction the error correction mechanism is operating primarily through the adjustment of the spot prices rather than the futures prices. Our findings are consistent with those reported for the Taiwan market by Lin, Chen and Hwang (2002) who also find that most of the price discovery happens in index spot market.

5. Conclusions

The extant literature on the impact of lower tick sizes on spot market liquidity and futures pricing efficiency provides a mixed picture. While many suggest that lower tick sizes reduce trading costs and improve efficiency, some studies show that they adversely affect the liquidity as well pricing efficiency. Moreover, there is no evidence hitherto on the impact of a major microstructure change introduced in the emerging Malaysian market. As far as we are aware, this is the first study to provide evidence of the impact of the lowering of tick sizes on the pricing efficiency of FBM-FKLI index futures.

Our findings show a significant increase in unexpected trading volume in the spot market and the speed of mean reversion of the futures mispricing following the introduction of lower tick sizes. There are two components of the unexpected spot trading volume. One represents arbitrage trades that serve to narrow down mispricing (Henker and Martens, 2005). The other represents trades to exploit firm specific information, which may strengthen or weaken the cash/futures pricing system, i.e. mispricing. If the unexpected spot trading volume is the result of efficient incorporation of stock specific information, the mispricing is expected to narrow down (Alexander, 2008, p.67; Chordia, Roll and Subrahmanyam, 2008). However, mispricing may widen if the unexpected spot trading volume represents trades that cause the index futures to delay in responding to both firm specific and market-wide information (Sutcliffe, 2006, p.162). Similarly, if arbitrageurs' trades, in the composition of the unexpected spot trading volume, exceed those trading on stock specific information, it is anticipated that mispricing will narrow down and vice versa (Cummings and Frino, 2011). Thus, the speed at which the mispricing reverts to its mean i.e. zero is determined by the composition of the unexpected spot trading volume. Therefore, the relationship between the unexpected trading volume in the spot market and the speed of mean reversion of the futures mispricing is attributed to that the fact that the futures mispricing process is, itself, a function of both the efficiency of pricing in the futures and in the underlying spot markets. As the increased unexpected trading volume in the underlying spot market would be anticipated to increase the informational efficiency of spot prices, the mean reversion in the mispricing process would be anticipated to increase as the informational efficiency becomes more equivalent in the two markets, assuming futures prices are the more efficient prices. We find that the speed at which the index futures revert to equilibrium prices is significantly lower, while the stock index adjusts to its equilibrium level much more quickly. This suggests that the reduction in tick size in the spot market leads to an increase in equilibrium convergence relative to the futures market. The equilibrium convergence in the futures market depends upon two factors; spot market efficiency/convergence and arbitrage processes. The combination of the two factors in the futures market can cause this relative reversion difference. Overall, our findings show that the reduction of tick sizes improves price discovery in the underlying spot market, while the leading role of index futures is weaker in the post tick size period. This suggests that the futures market incorporates information more rapidly than the spot market as the futures market leads the spot market both pre and post the tick size introduction. However, the improvement in spot market price discovery post the tick size change indicates that the degree of superior informational efficiency in the futures market relative to the spot is lesser with the result that the futures market leads the spot market to a lesser extent post the tick size change. The empirical evidence reported in the paper relating to the relationship between the unexpected trading volume in spot market and the speed of mean reversion of the futures mispricing offers useful policy implications for other emerging markets regarding the lowering of tick sizes and its effects on liquidity and pricing efficiency.

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Table 1: Descriptive Statistics of Trading Activity and Absolute Percentage Daily Changes in Trading Activity [a]

	Pre-tick size reduction	Post-tick size reduction	Whole Sample
Panel A: FBM-KLCI Stock Index			
A1: Level of Spot Volume (in Thousands of Ringgit Malaysia)			
N	1864	840	2704
Mean	566,505.790	777,680.544	632,107.415
Std. Dev. (σ)	413,242.444	279,378.690	389,205.056
Coefficient of variation (CV)[b]	0.729	0.359	0.616
Minimum	19,029.000	254,268.000	19,029.00
Maximum	3,300,398.000	2,744,341.00	3,300,398.00
A2: Absolute daily % changes in Spot Volume			
N	1863	840	2703
Mean	25.665	23.302	24.931
Std. Dev. (σ)	28.057	24.898	27.132
Minimum	0.017	0.001	0.001
Maximum	483.825	312.214	483.825
Panel B: FBM-FKLI Index Futures			
B1: Level of Futures Volume (in Thousands of Ringgit Malaysia)			
N	1864	840	2704
Mean	247,830.20	464,524.50	315,146.50
Std. Dev. (σ)	258,791.40	257,081.00	277,008.30
Coefficient of variation (CV)[b]	1.044	0.553	0.879
Minimum	0.000	0.000	0.000
Maximum	1,705,703.00	1,985,066.00	1,985,066.00
B2: Absolute daily % changes in Futures Volume			
N	1863	840	2703
Mean	13.54413	10.8734	12.7159
Std. Dev. (σ)	70.94209	56.729	66.85941
Minimum	0.001	0.011	0.001
Maximum	1,438.325	422.534	1,438.325

Note:

[a] The whole sample period is from 2 January 2002 to 31 December 2012. The pre-tick period is from 2 January 2002 to 2 August 2009, and the post-tick period is from 3 August 2009 to 31 December 2012.

[b]The coefficient of variance is calculated as: $CV = \frac{\sigma}{\mu}$

Table 1 provides summary statistics of daily trading activities for the constituents stocks and the index futures, before and after the reduction of tick sizes as well as for the whole sample period considered in the study. Panel A shows the summary statistics for the value of shares traded in Malaysian Ringgit (RM), while, Panel B shows the summary statistics for the value of futures contracts traded during the day. The volume of trading of both constituent stocks and futures contracts is significantly higher in post-tick period. The CV for both are lower in the post tick size period.

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Table 2: Descriptive Statistics for the Mispricing of Index Futures and Speed of Mean Reversion [a]

Descriptive statistics	Pre-tick size reduction	Post-tick size reduction	Whole sample
Panel A (x_{f_t})			
Mean	-0.368	-0.050	-0.269
t-statistic	-13.032[b]	-3.875[b]	-13.409[b]
F-statistic		-7.417[d]	
Standard deviation	1.219	0.371	1.044
First-order autocorrelation	0.827	0.470	0.817
First-order autocorrelation (changes)	-0.351	-0.491	-0.368
Panel B ($\|x_{f_t}\|$)			
Mean	0.994	0.297	0.777
t-statistic	53.844[b]	37.801[b]	54.114[b]
F-statistic		-24.899[d]	
Standard deviation	0.797	0.227	0.747
First-order autocorrelation	0.702	0.272	0.745
First-order autocorrelation (changes)	-0.376	-0.509	-0.387
Panel C (x_{s_t})			
Mean	-0.239	-0.083	-0.190
t-statistic	-12.095[b]	-6.827[b]	-13.415[b]
F-statistic		-5.112[d]	
Standard deviation	0.853	0.352	0.738
First-order autocorrelation	0.686	0.309	0.662
First-order autocorrelation (changes)	-0.373	-0.473	-0.389
Panel D ($\|x_{s_t}\|$)			
Mean	0.662	0.278	0.542
t-statistic	48.523[b]	34.980[b]	52.674[b]
F-statistic		18.259[d]	
Standard deviation	0.589	0.230	0.536
First-order autocorrelation	0.542	0.189	0.571
First-order autocorrelation (changes)	-0.409	-0.526	-0.422

Panel E: Estimate of the Mispricing Speed of Mean Reversion

	Before ETFs	After ETFs[▲]	After tick size reduction
Speed of mean reversion	-0.226[b]	-0.562[b]	-0.689[b]
p-value	(0.000)	(0.000)	(0.000)

[a] The whole sample period is from 1 January 2002 to 31 December 2012. The pre-tick period is from 1 January 2002 to 2 August 2009, and the post-tick period is from 3 August 2009 to December 2012. The ETFs was launched on the 19th July 2007

[b]Indicates significant at 1% level

[d]indicates average (absolute) mispricing is significantly different between the two sub-periods at 1% level.

Note: Table 2 reports the descriptive statistics and the mean reversion properties of the mispricing of index futures. Panel A and Panel B report the (absolute) mispricing as implied by the *underlying index* (Eq. (2)), while Panel C and Panel D report the (absolute) mispricing as implied by the *index futures* (Eq. (3)). In addition, Panel E reports the estimate of the mispricing speed of mean reversion as characterised in equation (4). Panels C and D of Table 2 report the descriptive statistics of mispricing and absolute mispricing calculated using equation (3). Panel E of Table 2 reports the speed of mean reversion for mispricing as estimated in equation (3).

Table 3: Descriptive statistics of the spot index and the index futures returns[a]

Descriptive Statistic		r_{s_t}			r_{f_t}	
	Pre-tick size reduction	Post-tick size reduction	Whole sample	Pre-tick size reduction	Post-tick size reduction	Whole sample
	1863	840	2703	1863	840	2703
Mean	0.029	0.043	0.034	0.028	0.043	0.033
Std. dev.	0.879	0.572	0.796	1.137	0.683	1.018
Skewness	-0.952	-0.449	-0.942	-0.528	-0.370	-0.550
Kurtosis	14.249	4.849	14.991	6.468	4.669	7.246
Jarque-Bera	10103.597	147.841	16592.987	1020.174	116.578	2166.851
[b]p-values	0.000	0.000	0.000	0.000	0.000	0.000

[a] The whole sample period runs from 2 January 2002 to 31 December 2012. While, the pre-and post-tick size reduction periods run from 2 January 2002 to 2 August 2009, and from 3 August 2009 to 31 December 2012, respectively. The returns of the stock index and index futures are defined as $r_{s_t} = 100 * \ln(\frac{S_t}{S_{t-1}})$ and $r_{f_t} = 100 * \ln(\frac{F_t}{F_{t-1}})$, respectively.

[b] p-values for the Jarque-Bera statistics

Table 4: Estimates of daily change in trading volume (in millions of Ringgit)

	Coefficient	Standard errors
Intercept	-30.624***	(6.554)
ΔSR_t	0.3334	(138.160)
ΔTS_t	0.1477*	(47.862)
ΔQS_t	0.0553*	(38.614)
$\lvert\Delta P_t\rvert$	37.329***	(3.268)
MKT	19.085***	(4.086)
$d_1(monday)$	-34.759***	(10.124)
$d_2(tuesday)$	25.563***	(9.334)
$d_3(wednesday)$	3.893	(8.982)
$d_4(thursday)$	14.848	(9.708)
$tick$	10.886***	(2.564)
ΔV_{t-1}	-0.404***	(0.020)
ΔV_{t-2}	-0.296***	(0.022)
ΔV_{t-3}	-0.214***	(0.025)
ΔV_{t-4}	-0.164***	(0.023)
ΔV_{t-5}	-0.092***	(0.024)
ΔV_{t-6}	-0.134***	(0.026)
ΔV_{t-7}	-0.085***	(0.027)
ΔV_{t-8}	-0.041	(0.027)
ΔV_{t-9}	-0.020	(0.023)
ΔV_{t-10}	-0.006	(0.019)
$ARCH-1$	0.149***	(0.009)
$GARCH-1$	0.866***	(0.007)
Constant	525.028***	(60.520)
Observations	2,703	

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The table reports the estimates of the equation (8). The dependent variable is the daily changes in trading volume (in millions of Ringgit). The model is fitted using ARMA (10, 0)-GARCH (1, 1) specification.

$$\Delta V_t = \alpha + \beta_1 \Delta SR_t + \beta_2 \Delta TS_t + \beta_3 \Delta QS_t + \beta_4 \Delta MKT_t + \beta_5 |\Delta P_t| + \sum_{i=1}^{n} \varphi_i \Delta V_{t-i} + \sum_{j=1}^{4} \delta_i d_j + \beta_6 tick_t + \varepsilon_t \quad (8)$$

Kuala Lumpur Inter-Bank Offered overnight Rate (KLIBOR) is the proxy for short-term rates. Term spread is the difference between the short-term rates and the 10-year Malaysian Government Securities (MGS) continuously compounded annualised yield. Quality spread (QS) is the difference between the yield on Bank Negara Malaysia's (BNM) AAA 10-year Private Debt Securities (PDS) and 10-year MGS yield. MKT is the dummy variable to proxy for concurrent market performance. It takes the value 1 if the concurrent spot index return is positive, and zero otherwise. $|\Delta P_t|$ is the absolute change in spot index price, which is the proxy for the market volatility. ΔV_{t-i} is the lag(s) of the daily trading volume to account for the momentum effect. d_j is the dummy for day of the week to capture daily variation in trading volume. $tick$ is dummy variable which is equal to 1 following the implementation of tick size reduction.

Table 5: Estimates of the daily absolute futures mispricing regression

Variables	x_{f_t}	Standard errors	x_{s_t}	Standard errors
Constant	0.865***	(0.039)	0.926***	(0.046)
$tick$	-0.294***	(0.114)	-0.493***	(0.137)
$crisis$	0.460***	(0.152)	0.403**	(0.174)
etf	-0.290**	(0.114)	-0.146	(0.132)
V_t^{spot}	0.011***	(0.000)	0.021**	(0.000)
$V_t^{futures}$	0.041**	(0.020)	0.037**	(0.020)
$Vol_t^{futures}$	0.013**	(0.014)	0.019**	(0.014)
$V_t^{futures} * tick$	-0.028**	(0.024)	-0.019**	(0.026)
$V_t^{spot}\ tick$	-0.017**	(0.000)	-0.050**	(0.000)
AR(1)	0.377***	(0.020)	1.605***	(0.177)
AR(2)	0.177***	(0.022)	-0.627***	(0.161)
AR(3)	0.094***	(0.021)	-	
AR(4)	0.039*	(0.022)	-	
AR(5)	0.050**	(0.022)	-	
AR(6)	0.035*	(0.020)	-	
MA(1)	-		-1.192***	(0.180)
MA(2)	-		0.309***	(0.100)
ARCH(1)	0.109***	(0.008)	0.125***	(0.011)
GARCH(1)	0.896***	(0.008)	0.881***	(0.010)
Constant	0.001***	(0.000)	0.001***	(0.000)
Observations	2,703		2,703	

Note : Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table reports the coefficient estimates of equation (9), i.e. $|x_{f_t}| = \beta_0 + \beta_1 tick + \beta_2 etf + \beta_3 crisis + \beta_4 V_t^{futures} + \beta_5 V_t^{spot} + \beta_6 Vol_t^{futures} + \beta_7(V_t^{spot} * tick) + \beta_8(V_t^{futures} * tick) + \sum_{i=1}^{p} \varphi |x_{f_{t-i}}| + \sum_{j=1}^{q} e_{t-j} + e_t$. The dependent variable is x_{f_t}as defined in equation (2) or x_{s_t} as defined in equation (3). $tick$ is a dummy variable which is equal to 1 following the reduction of tick size i.e. 3 August 2009. $crisis$ is also a dummy variable which is equal to 1 for the period from 16 January 2008 to 10 March 2009. etf is a dummy variable which is equal to 1 from 19 July 2007 onwards. $V_t^{futures}$is the unexpected futures trading volume and V_t^{spot} is the unexpected ringgit trading volume. $Vol_t^{futures}$is the futures volatility. $V_t^{spot}\ tick$ and $V_t^{futures} * tick$ are the interaction between unexpected spot trading volume, unexpected futures volume and tick, respectively. An AR (6)-GARCH (1, 1) and ARMA (2, 2)-GARCH (1, 1) are fitted to explain daily variation in x_{f_t} and x_{s_t} , respectively. Mispricing is highly significant as indicated by the constant coefficient.

Table 6: Mispricing analyses for the Relationship between FBM-KLCI Stock Index and FBM-FKLI Index Futures Using OLS and Quantile Regressions

	OLS	Q(0.99)	Q(0.9)	Q(0.75)	Q(0.5)	Q(0.25)	Q(0.1)	Q(0.01)
$tick$	-0.094***	-0.385**	-0.397***	-0.199***	-0.016**	0.053**	0.032**	0.002**
	(0.031)	(0.055)	(0.080)	(0.074)	(0.040)	(0.025)	(0.022)	(0.009)
$crisis$	0.051	0.769***	0.204	0.100	0.037	0.006	-0.004	-0.009
	(0.037)	(0.289)	(0.135)	(0.095)	(0.045)	(0.034)	(0.026)	(0.014)
etf	-0.020**	-0.009**	0.158**	0.028**	-0.052**	-0.075**	-0.047**	-0.002**
	(0.029)	(0.021)	(0.078)	(0.076)	(0.039)	(0.029)	(0.020)	(0.010)
V_t^{spot}	-0.015**	0.000	-0.000	-0.021**	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$V_t^{futures}$	0.187***	1.028***	0.391***	0.263***	0.110***	0.064**	0.034*	0.005
	(0.023)	(0.140)	(0.059)	(0.035)	(0.022)	(0.029)	(0.018)	(0.008)
$Vol_t^{futures}$	0.063***	0.582***	0.135***	0.061**	0.024	0.008	0.011	-0.002
	(0.020)	(0.147)	(0.051)	(0.029)	(0.020)	(0.018)	(0.013)	(0.004)
$V_t^{futures} * tick$	-0.135***	-0.899**	-0.216***	-0.163***	-0.061**	-0.055*	-0.010	-0.005
	(0.044)	(0.386)	(0.068)	(0.055)	(0.026)	(0.031)	(0.024)	(0.009)
$V_t^{spot} * tick$	-0.026***	-0.013***	0.000	-0.017*	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\lvert x_{f_{t-1}} \rvert$	0.360***	0.561***	0.585***	0.498***	0.362***	0.221***	0.103***	0.005
	(0.019)	(0.150)	(0.046)	(0.056)	(0.034)	(0.025)	(0.020)	(0.013)
$\lvert x_{f_{t-2}} \rvert$	0.185***	0.386**	0.187***	0.200***	0.167***	0.124***	0.085***	0.015
	(0.020)	(0.177)	(0.039)	(0.044)	(0.026)	(0.022)	(0.016)	(0.009)
$\lvert x_{f_{t-3}} \rvert$	0.044**	0.009	0.011	0.062	0.053*	0.068***	0.020	0.006
	(0.021)	(0.116)	(0.052)	(0.042)	(0.032)	(0.025)	(0.014)	(0.010)
$\lvert x_{f_{t-4}} \rvert$	0.069***	0.104	0.126***	0.084**	0.033	0.031	0.008	0.013*
	(0.021)	(0.107)	(0.034)	(0.040)	(0.026)	(0.022)	(0.021)	(0.008)
$\lvert x_{f_{t-5}} \rvert$	-0.007	0.105	-0.004	0.018	0.037	0.004	-0.004	-0.008*
	(0.020)	(0.167)	(0.059)	(0.028)	(0.029)	(0.017)	(0.024)	(0.005)
$\lvert x_{f_{t-6}} \rvert$	0.027	0.113	0.049	0.023	0.012	0.016	0.008	0.007
	(0.019)	(0.118)	(0.041)	(0.037)	(0.028)	(0.014)	(0.015)	(0.006)
Constant	0.175***	0.773***	0.465***	0.291***	0.126***	0.024	0.007	-0.004
	(0.021)	(0.156)	(0.039)	(0.025)	(0.020)	(0.017)	(0.015)	(0.007)
Observations	2,691	2,691	2,691	2,691	2,691	2,691	2,691	2,691
R-squared	0.401	0.456	0.396	0.308	0.203	0.11	0.048	0.011

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The change in average futures absolute mispricing after the reduction of tick sizes is tested by an autoregressive model with six lags, as identified via the partial autocorrelation function, defined in the following equation:

$$\lvert x_{f_t} \rvert = \beta_0 + \beta_1 tick + \beta_2 etf + \beta_3 crisis + \beta_4 V_t^{futures} + \beta_5 V_t^{spot} + \beta_6 Vol_t^{futures} + \beta_7 (V_t^{spot} * tick) + \beta_8 (V_t^{futures} * tick) + \sum_{i=1}^{p} \varphi \lvert x_{f_{t-i}} \rvert + e_t$$

$\lvert x_{f_t} \rvert$ is the average absolute mispricing, defined in equation (2), at time t ; $tick$ is a dummy variable which is equal to 1 following the reduction of tick size i.e. 3 August 2009. $crisis$ is also a dummy variable which is equal to 1 for the period from 16 January 2008 to 10 March 2009. etf is a dummy variable which is equal to 1 from 19 July 2007 onwards. $V_t^{futures}$

is the unexpected futures trading volume and V_t^{spot} is the unexpected ringgit trading volume. $Vol_t^{futures}$ is the futures volatility. $V_t^{spot} * tick$ and $V_t^{futures} * tick$ are the interaction between unexpected spot trading volume, unexpected futures volume and tick dummy, respectively. In addition, six lags of the dependent variable in the regression model are employed to eliminate autocorrelation in the residuals. OLS method and linear quantile regression are adopted to estimate this equation.

Table 7: Mispricing analyses for the Relationship between FBM-KLCI Stock Index and FBM-FKLI Index Futures Using OLS and Quantile Regressions

	OLS	Q(0.99)	Q(0.9)	Q(0.75)	Q(0.5)	Q(0.25)	Q(0.1)	Q(0.01)
$tick$	-0.091***	-0.391**	-0.402***	-0.176***	-0.017**	0.048**	0.036*	-0.002**
	(0.032)	(0.061)	(0.076)	(0.047)	(0.035)	(0.023)	(0.021)	(0.006)
$crisis$	0.057	0.708***	0.216**	0.112	0.055	0.011	-0.002	-0.005
	(0.037)	(0.261)	(0.096)	(0.085)	(0.060)	(0.050)	(0.024)	(0.016)
etf	-0.026**	-0.002**	0.166**	0.003	-0.063	-0.072***	-0.047**	0.006*
	(0.030)	(0.036)	(0.077)	(0.051)	(0.043)	(0.022)	(0.021)	(0.006)
V_t^{spot}	-0.021**	0.000	-0.000	-0.000	-0.017**	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$V_t^{futures}$	0.186***	1.021***	0.414***	0.258***	0.102***	0.065***	0.010	0.001
	(0.024)	(0.132)	(0.043)	(0.047)	(0.025)	(0.023)	(0.015)	(0.007)
$Vol_t^{futures}$	0.061***	0.557***	0.119***	0.063**	0.021	0.003	-0.005	0.005
	(0.020)	(0.126)	(0.044)	(0.029)	(0.018)	(0.011)	(0.011)	(0.004)
$V_t^{futures} * tick$	-0.135***	-0.879**	-0.243***	-0.151**	-0.067**	-0.050*	0.011	-0.002
	(0.044)	(0.414)	(0.073)	(0.070)	(0.032)	(0.026)	(0.022)	(0.009)
$V_t^{spot} * tick$	-0.023**	0.017***	0.000	0.000	-0.011**	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\lvert x_{s_{t-1}} \rvert$	0.361***	0.530***	0.561***	0.500***	0.356***	0.236***	0.107***	0.009
	(0.019)	(0.100)	(0.052)	(0.036)	(0.036)	(0.031)	(0.020)	(0.010)
$\lvert x_{s_{t-2}} \rvert$	0.189***	0.393**	0.195***	0.202***	0.168***	0.114***	0.086***	0.008
	(0.020)	(0.161)	(0.039)	(0.044)	(0.025)	(0.019)	(0.019)	(0.006)
$\lvert x_{s_{t-3}} \rvert$	0.046**	-0.016	0.027	0.085*	0.068***	0.065***	0.036	0.009*
	(0.021)	(0.123)	(0.049)	(0.048)	(0.024)	(0.019)	(0.022)	(0.005)
$\lvert x_{s_{t-4}} \rvert$	0.059***	0.122	0.127**	0.047	0.029	0.039	0.001	-0.005
	(0.021)	(0.111)	(0.050)	(0.037)	(0.036)	(0.024)	(0.022)	(0.005)
$\lvert x_{s_{t-5}} \rvert$	0.001	0.145	-0.010	0.034	0.035	0.001	0.013	0.004
	(0.020)	(0.174)	(0.039)	(0.036)	(0.037)	(0.019)	(0.017)	(0.009)
$\lvert x_{s_{t-6}} \rvert$	0.028	0.088	0.061	0.020	0.022	0.016	0.003	0.002
	(0.019)	(0.151)	(0.048)	(0.032)	(0.028)	(0.016)	(0.011)	(0.007)
Constant	0.177***	0.830***	0.472***	0.292***	0.129***	0.027	-0.002	-0.006
	(0.022)	(0.111)	(0.029)	(0.032)	(0.022)	(0.018)	(0.011)	(0.009)
Observations	2,691	2,691	2,691	2,691	2,691	2,691	2,691	2,691
R-squared	0.406	0.452	0.396	0.312	0.212	0.117	0.052	0.008

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: The change in average futures absolute mispricing after the reduction of tick sizes is tested by an autoregressive model with six lags, as identified via the partial autocorrelation function, defined in the following equation:

$$\lvert x_{f_t} \rvert = \beta_0 + \beta_1 tick + \beta_2 etf + \beta_3 crisis + \beta_4 V_t^{futures} + \beta_5 V_t^{spot} + \beta_6 Vol_t^{futures} + \beta_7 (V_t^{spot} * tick) + \beta_8 (V_t^{futures} * tick) + \sum_{i=1}^{p} \varphi \lvert x_{f_{t-i}} \rvert + e_t$$

Table 8: Estimates of partial-adjustment factors[a]

Sample frame	g_i				Non-Random Walk	
	Cross-covariance ratio	AR(1)	ARMA(1,1)	ARMA(1,X)[b]	γ_i	g_i
<u>Whole data set</u>						
g_f	0.988	1.050*	1.305	1.305	1.000**	1.176**
g_s	0.744	0.869*	0.830	0.869*	1.000**	0.721**
<u>Pre-tick</u>						
g_f	0.993	1.048*	1.192	1.192	1.000**	1.182**
g_s	0.743	0.867*	1.134	0.737	1.000**	0.714**
<u>Post-tick</u>						
g_f	0.959	1.068*	1.716*	1.716*	1.000**	1.145**
g_s	0.751	0.876*	0.692	0.876*	1.000**	0.763**

The whole sample frame comprises the period from 2 January 2002 to 31 December 2012; pre-tick period is from 2 Jan 2002 - 2 August 2009 and post-tick is from 3 Aug 2009 to 31 Dec 2012.
[b] The optimal MA components are determined by the Akaike Information Criterion (AIC).
* Statistically significantly different from one at the 5% significance level. Equivalently, $(1 - g_i)$ is significantly different from zero at 5% level.
**Statistically significantly different from zero at the 5% significance level.

Appendix A: Summary Statistics for Debt and Equity Market Explanatory Variables

	SR	TS	QS	Stocks (%/day)
		Levels		
N	2704	2704	2704	2703
Mean	2.977	1.210	1.137	0.034
Std. Dev.	0.464	0.744	0.171	0.796
Minimum	2.030	-0.506	0.598	-9.979
Maximum	3.647	2.695	2.032	4.259
			First Differences	
N	2703	2703	2703	
Mean	0.000	-0.000	-0.000	
Std. Dev.	0.023	0.065	0.079	
Minimum	-0.784	-0.604	-0.676	
Maximum	0.307	0.738	0.588	

SR : Yield on overnight Kuala Lumpur Inter-Bank Offered Rate (KLIBOR), the proxy for short-term interest rates.
TS : Yield spread between the constant maturity 10-year Treasury bond and the overnight KLIBOR, the proxy for term spread.
QS : Yield spread between Bank Negara Malaysia (BNM), i.e. The Central Bank of Malaysia, Grade AAA 10-year Private Debt Securities (PDS) and the constant maturity 10-year Treasury bond, the proxy for quality spread.

Table A1: Causality testing using VECM for the pre-tick reduction period

Panel A: Futures returns as dependent variable

Independent variable	Coefficient	Standard error	z	p>¦z¦
$\hat{z}_{t-1}$	-0.142	0.0401	-3.54	0.000
ΔF_{t-1}	-0.0765	0.0527	-1.45	0.146
ΔF_{t-2}	-0.00381	0.0538	-0.07	0.943
ΔF_{t-3}	-0.0185	0.0519	-0.36	0.722
ΔF_{t-4}	0.0749	0.0449	1.67	0.095
ΔS_{t-1}	0.116	0.0634	1.83	0.068
ΔS_{t-2}	0.0178	0.0631	0.28	0.777
ΔS_{t-3}	0.106	0.0612	1.73	0.083
ΔS_{t-4}	-0.0662	0.0525	-1.26	0.207
α_2	0.000127	0.0002	0.48	0.630

Panel B: Spot returns as dependent variable

Independent variable	Coefficient	Standard error	z	p>¦z¦
$\hat{z}_{t-1}$	0.0619	0.0303	2.04	0.041
ΔF_{t-1}	0.247	0.0398	6.22	0.000
ΔF_{t-2}	0.136	0.0406	3.34	0.001
ΔF_{t-3}	0.0939	0.0392	2.40	0.017
ΔF_{t-4}	0.0999	0.0339	2.95	0.003
ΔS_{t-1}	-0.160	0.0479	-3.34	0.001
ΔS_{t-2}	-0.138	0.0477	-2.89	0.004
ΔS_{t-3}	-0.0418	0.0462	-0.90	0.366
ΔS_{t-4}	-0.0919	0.0396	-2.32	0.020
α_1	0.000292	0.0001	1.46	0.143

Note: The table shows the VECM estimates for the pre-tick period. The equations used are: $\Delta F_t = \alpha_1 + \alpha_F \hat{Z}_{t-1} + \sum_{i=1}^{n} \alpha_{21}(i)\Delta S_{t-i} + \sum_{i=1}^{n} \alpha_{22}(i)\Delta F_{t-i} + e_{F_t}$ and $\Delta S_t = \alpha_1 + \alpha_S \hat{Z}_{t-1} + \sum_{i=1}^{n} \alpha_{11}(i)\Delta S_{t-i} + \sum_{i=1}^{n} \alpha_{12}(i)\Delta F_{t-i} + e_{S_t}$. The estimates of the former equation is presented in Panel A and the estimates of the latter equation is presented in Panel B. Panel B of Table A1 shows that the coefficients of ΔF_{t-i} are positive and significant.

Table A2: Causality testing using VECM for the post-tick reduction period

Panel A: Futures returns as dependent variable				
Independent variable	Coefficient	Standard error	z	$P>\|z\|$
$\hat{z}_{t-1}$	-0.140	0.112	-1.25	0.211
ΔF_{t-1}	-0.195	0.113	-1.72	0.086
ΔF_{t-2}	-0.051	0.108	-0.47	0.637
ΔF_{t-3}	0.037	0.097	0.39	0.699
ΔF_{t-4}	0.076	0.074	1.03	0.304
ΔS_{t-1}	0.240	0.118	2.05	0.041
ΔS_{t-2}	0.104	0.111	0.94	0.346
ΔS_{t-3}	-0.091	0.099	-0.91	0.363
ΔS_{t-4}	-0.043	0.076	-0.56	0.575
α_2	0.000479	0.0002	1.99	0.047

Panel B: Spot returns as dependent variable				
Independent variable	Coefficient	Standard error	z	$P>\|z\|$
$\hat{z}_{t-1}$	0.324	0.091	3.55	0.000
ΔF_{t-1}	0.124	0.093	1.34	0.179
ΔF_{t-2}	0.103	0.088	1.17	0.242
ΔF_{t-3}	0.120	0.079	1.52	0.128
ΔF_{t-4}	0.062	0.061	1.02	0.306
ΔS_{t-1}	-0.051	0.096	-0.53	0.596
ΔS_{t-2}	-0.054	0.090	-0.60	0.546
ΔS_{t-3}	-0.181	0.081	-2.22	0.026
ΔS_{t-4}	-0.050	0.063	-0.80	0.424
α_1	0.000207	0.0001	1.06	0.291

Note: The table shows the VECM estimates for the pre-tick period. The equations used are: $\Delta F_t = \alpha_1 + \alpha_F \hat{Z}_{t-1} + \sum_{i=1}^{n} \alpha_{21}(i)\Delta S_{t-i} + \sum_{i=1}^{n} \alpha_{22}(i)\Delta F_{t-i} + e_{F_t}$ and $\Delta S_t = \alpha_1 + \alpha_S \hat{Z}_{t-1} + \sum_{i=1}^{n} \alpha_{11}(i)\Delta S_{t-i} + \sum_{i=1}^{n} \alpha_{12}(i)\Delta F_{t-i} + e_{S_t}$. The estimates of the former equation is presented in Panel A and the estimates of the latter equation is presented in Panel B. Panel B of Table A2, shows that the coefficients of ΔF_{t-i} are insignificant.