An Empirical Analysis of the Dynamic Probability of Institutional Informed Trading: Evidence from the Taiwan Futures Exchange

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ABSTRACT

This paper analyzes the informational role of institutional investors' trading using the dynamic intraday measure of the probability of informed trading (hereafter DPIN). Using a unique account-level dataset of institutional investors from the Taiwan index futures market, we show that the DPINs of foreign institutional buy trades are significantly positively related to future market returns. Moreover, compared to using trading imbalance as the informed trading measure, we find that the DPIN provides consistent predictive power for the market volatility, particularly during intense trading periods. Overall, our results also provide support for the notion that foreign institutional traders are better informed than domestic institutional traders in the emerging markets.

Keywords: Institutional investors; Probability of informed trading; Emerging markets

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ABSTRACT

This paper analyzes the informational role of institutional investors' trading using the dynamic intraday measure of the probability of informed trading (hereafter DPIN). Using a unique account-level dataset of institutional investors from the Taiwan index futures market, we show that the DPINs of foreign institutional buy trades are significantly positively related to future market returns. Moreover, compared to using trading imbalance as the informed trading measure, we find that the DPIN provides consistent predictive power for the market volatility, particularly during intense trading periods. Overall, our results also provide support for the notion that foreign institutional traders are better informed than domestic institutional traders in the emerging markets.

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1. INTRODUCTION

The informed trading of institutional investors has been studied for more than 40 years in the literature (e.g., Kraus and Stoll, 1972; Chakravarty, 2001; Saar, 2001; Chiyachantana et al., 2004; Yan and Zhang, 2009; Dasgupta, Prat and Verardo, 2011; Puckett and Yan, 2011).[2] If institutional investors are informed with regard to undervalued or overvalued stocks, their trading will speed up the adjustment of fundamental values for stock prices. As such, institutional investors' trading behavior would be likely to stabilize the stock market and improve market efficiency. On the other hand, institutions may not fully take advantage of their information in investments and thus provide only little evidence of stock-picking skill because of the limits of arbitrage (Cohen, Gompers and Vuolteenaho, 2002; Lewellen, 2011).

The study of how institutional investors employ their information is of continual interest to both practitioners and academics; however, measuring the information of transactions for institutional investors is not an easy task. One of the most common and widely accepted methods is the probability of informed trading (PIN), successively developed by Easley, Kiefer, O'Hara and Paperman (1996), Easley, Kiefer and O'Hara (1997a, b) and Easley, Hvidkjaer and O'Hara (2002).[3] Although

[2] Kraus and Stoll (1972) find that block trades can affect market efficiency. Chakravarty (2001) confirms the influenced of informed trading on medium-size trades in favor of the stealth-trading hypothesis. Saar (2001) and Chiyachantana et al. (2004) both investigate the information content of institutional trades. Dasgupta, Prat and Verardo (2011) provide a theoretical equilibrium model to confirm the association between institutional herd behavior and both short- and long-term returns.

[3] The PIN measure is generally used in many fields of corporate finance, investment, and market

the PIN has been widely accepted in previous studies, it is also well-known for its difficulty in capturing short-lived information.[4] Recently, Chang, Chang and Wang (2014) have extended the ACG (Avramov, Chordia and Goyal, 2006) model to construct a dynamic intraday version of the PIN (hereafter DPIN) and allow researchers to estimate the probability of informed trading at much finer frequencies.[5] Chang et al.'s (2014) DPIN is a newly developed measure that provides intuitive explanation and friendly application. These advantages make the DPIN an attractive alternative for directly determining the information content of all kinds of transactions in the market. To date, the DPIN has received little examination in the literature, and thus this paper seeks to examine different types of institutional trading using the DPIN and provide further evidence for its application.

We select an emerging market, the Taiwan futures exchange (TAIFEX), as our target to conduct the examination. Using a unique dataset from the TAIFEX, we can precisely classify domestic institutional transactions and foreign institutional transactions. Given the general viewpoint that foreign institutional traders may enjoy

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microstructure, for example, in the studies of Easley et al. (1996), Brown et al. (2004), Vega (2006), Zhao and Chung (2006), Chan et al. (2008), Duarte and Young (2008), and Brockman and Yan (2009).

[4] In order to estimate the PIN measure, one must aggregate very fine intraday data, which occur at approximately five-minute intervals within the trading day across multiple days (Easley et al., 1997a, b). The resulting estimate measures informed trading over a very long horizon from one month to one quarter. In addition, over such long horizons it is likely that the actual impact of short-lived private information may become diluted or masked by other factors.

[5] Specifically, at 15-minute intervals throughout the trading day, such frequencies being more in line with the speed at which traders react to and digest information in modern financial markets. Our dynamic DPIN measure may be better suited to capturing information based on trading activity at higher frequencies, even within the trading day.

an information advantage over domestic institutional traders in a local market such as the TAIFEX,[6] the advantage of our dataset is relevant for our analyses. Comparing different types of institutional trading using the DPIN, we can test whether it captures informed trading well, and also investigate the information content of foreign and domestic institutional trades.

As a comparison to the DPIN, we also use the trade imbalance (TIB) to examine the information content of different institutional trading.[7] Some previous studies have examined the information content of trading by testing the price impact of trading activities. Of these, many use TIB to measure trading activity as this measure can proxy for both of the direction and magnitude of price changes (see, e.g., Chordia, Roll and Subrahmanyam, 2008; Easley, Engle, O'Hara and Wu, 2008; Subrahmanyam, 2008; Barber, Odean and Zhu, 2009; O'Hara, Yao and Ye, 2011).[8] Therefore, in addition to providing further empirical evidence on the application of the DPIN, this study also compares the difference (if any) between the newly developed measure (DPIN) and the conventional measure (TIB). By doing so, we believe we can enhance

[6] For example, several prior studies (Grinblatt and Keloharju, 2000; Huang and Shiu, 2009) show that foreign institutional investors are more likely to select winners in the markets than domestic investors, implying that foreign institutional traders are better informed than their local competitors.

[7] Kyle (1985) and Admati and Pfleiderer (1988) focus on order imbalance as a signal of informed trades. It is assumed in these models that market makers will adjust prices upwards (downwards) when there are excess buy (sell) orders.

[8] Chordia, Roll and Subrahmanyam (2002, p.112) describe a simple and clear case: "Consider, for example, a reported volume of one million shares. At one extreme, this might be a million shares sold to the market maker while at the other extreme it could be a million shares purchased. Perhaps more typically, it would be roughly split, about 500,000 shares sold to and 500,000 shares bought from the market maker. Each scenario has its own specific implications for price movement or liquidity changes."

our understanding of the proxy of informed trading.

To study the validity of the DPIN and the TIB for both domestic and foreign institutional investors, we test return impact and volatility impact for each measure. Chang, Hsieh and Wang (2009) show that foreign institutional traders are better informed concerning price movements and variations than domestic traders in the local market; in the same vein, we consider both return and volatility in our analyses.

Our empirical findings are summarized as follows. First, we show that the DPIN of foreign institutional buying trades is significantly positively related to the market return. This finding suggests that the DPIN is able to capture informed trading on the buying side of foreign institutional traders. Second, we show that the DPIN as the informed measure provides more stable performance than the TIB for volatility predictability, particularly during an intense trading interval within a day. The overall results indicate that the DPIN is more suitable for measuring the informed trading of foreign institution investors than the TIB.

For domestic institutional traders, we find weak prediction of returns, revealing that the DPIN does not fully measure the informed trading of domestic institutional traders. Return predictability for the domestic institutional DPIN can be found only during intense trading intervals, when the same cannot be seen using the TIB. On the other hand, the TIB and the DPIN of domestic institutional traders perform indifferently in relation to volatility impact. To sum up the findings regarding domestic institutional trading, the DPIN appears to have slightly better ability in measuring the informed trading of domestic institutional traders than the TIB.

Our investigation provides support not only for the information role of foreign institutional traders in the emerging market, but also contributes to the discussion regarding the validity of the DPIN in capturing short-lived information. Earlier studies usually report that foreign institution investors are better informed than other types of investors based on analysis using the PIN or the TIB. Our paper shows that the DPIN may be able to capture the information content of foreign institutional trading more accurately at higher frequencies. In the spirit of the definition of the DPIN given by Chang et al. (2014), the results also imply that foreign institutions are more likely to be contrarian traders, which is consistent with the argument of Barber and Odean (2011).

The remainder of this paper is organized as follows. Section 2 describes the data and methodology. Section 3 presents the empirical results for foreign institutional investors and domestic institutional investors. Section 4 concludes.

2. DATA and METHEDOLOGY

2.1 Data and variable definition

We obtain the transaction data for TXF contracts from the Taiwan Futures Exchange (TAIFEX).[9] TXF is the major and most actively traded index futures product on the TAIFEX. Our dataset covers the period from January 1, 2003 to December 31, 2007. The dataset contains the date and time of the transactions, the indicator of opening or closing position, the indicator of trading direction (buy or sell),[10] and the quantity demanded or offered. Most importantly, it provides the identification of traders, which enables us to categorize the type of trader as foreign institutions or domestic institutions. As our analysis focuses on intraday horizons, we divide a single trading day into twenty 15-minute trading intervals, with each buy or sell trade being assigned to one of these intervals, depending on when the trade occurred during the day.

As mentioned, we use two measures of institutional informed trading, the DPIN and the TIB, to investigate the trading behavior of foreign institutional investors. The DPIN is defined according to the model of Chang et al. (2014), whereas the TIB follows the general definition in the literature. All measures are calculated on the basis

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[9] At the end of 2007, TAIFEX was ranked 21 among 54 derivatives exchanges reported to the Futures Industries Association. The TAIFEX is ranked eighth among emerging markets. Trading on the TAIFEX is conducted from 8:45 AM to 1:45 PM Monday to Friday (excluding public holidays).

[10] Compared to Lee and Ready (1991), determining the method of trade direction allows us to measure the trading activities of the investors more accurately, eliminating the measurement errors of trading volume.

of 15-minute intervals. The return of index futures is computed by the first difference of the natural log of the mid-price of the bid–ask spread at the end of each intraday interval.[11] Our estimation for the volatility of index futures is consistent with the method of Kuo, Chung and Chang (2014).[12]

2.1.1 DPIN measure

Following Chang et al. (2014), the DPIN is constructed by extending the ACG model. The buy (sell) trades in the presence of negative (positive) unexpected returns are classified as informed trades, whereas buy (sell) trades in the presence of positive (negative) unexpected returns are classified as uninformed trades. To calculate the unexpected component of returns, we extract the residuals from the following regression:

$$R_t = \delta_0 + \sum_{k=1}^{4} \delta_{1,k} D_{kt}^{day} + \sum_{k=1}^{20} \delta_{2,k} D_{kt}^{Interval} + \sum_{k=1}^{6} \delta_{3,k} R_{t-k} + \varepsilon_t , \quad (1)$$

where R_t is the index futures returns at intraday interval *t*, D_{kt}^{day} represents day-of-week dummy variables for Tuesday through Friday, and $D_{kt}^{Interval}$ represents

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[11] The return of index futures is defined as the first difference of the natural log of the TAIFEX (S_t) in each trading interval: $R_t = 100 * (\ln S_t - \ln S_{t-1})$, the annualized rate of return multiplied by (20 × 252).

[12] We refer to Kuo et al. (2014) to construct the measure of volatility. We estimate a GARCH(1, 1) model to obtain the volatility of futures:

$$R_t = \alpha_0 + \varepsilon_t \quad \varepsilon_t | \Omega_{t-1} \sim N(0, h_t)$$
$$h_t = \eta_0 + \eta_1 \varepsilon_{t-1}^2 + \eta_2 h_{t-1} + \theta_3 TA_t$$

where R_t is the return of index futures at intraday interval *t*; TA_t is futures trading activity by total volume at interval *t*; Ω_{t-1} denotes the information set available up to time *t*; h_t is the conditional futures variance term at interval *t*; ε_{t-1}^2 are the lagged squared residuals from the return equation.

dummy variables corresponding to the particular 15-minute interval at which returns are measured. Thus, the residual ε_t captures the variation in returns left over after day-of-week effects, intraday time effects, and the effect of past returns have been accounted for, and therefore serves as a proxy for unexpected returns.

Let NB_t, NS_t, and NT_t represent the number of buy, sell, and total trades, respectively, for index futures returns at interval t. Then, the DPIN is constructed as follows:

$$DPIN_{base_t} = \frac{NB_t}{NT_t}(\varepsilon_t < 0) + \frac{NS_t}{NT_t}(\varepsilon_t > 0)\,, \qquad (2)$$

As can be seen, the DPIN represents the proportion of contrarian trades taking place during the 15-minute interval, which is based on the interpretation of Chang et al. (2014) regarding the trading behavior of informed investors.

2.1.2 TIB measure

Based on the general definition in the literature, e.g., Chordia and Subrahmanyan (2004), the trading imbalance (TIB) is defined as:

$$TIB_t = \frac{B_t - S_t}{B_t + S_t}\,, \qquad (3)$$

where B_t and S_t are the buying volume and selling volume of foreign institutional traders at interval t, respectively.

2.2 Regression specifications

2.2.1 The relation between returns and trading activities

First, we use the DPIN and the TIB as proxies of trading activities and examine their association with market returns. However, we would like to note that the DPIN measures the likelihood of informed trading and presents no signs, whereas the index future returns are signed in the positive (buy) or negative (sell) direction. Therefore, when we examine the relation between index future returns and DPINs, we separate the DPIN into $DPIN_{buy}$ and the $DPIN_{sell}$ accordingly. We perform the following time series regressions with Newey–West robust standard errors for institutional trading activities:

$$R_t = \alpha_0 + \sum_{k=1}^{4} \delta_k DPIN^i_{buy_{t-k}} + \sum_{k=1}^{4} \eta_k DPIN^i_{sell_{t-k}} + \sum_{k=1}^{4} \beta_k R_{t,k} + \varepsilon_t \tag{4}$$

$$R_t = \alpha_0 + \sum_{k=1}^{4} \gamma_k TIB^i_{t-k} + \sum_{k=1}^{4} \beta_k R_{t-k} + \varepsilon_t \; , \tag{5}$$

where R_t denotes the index futures return for the *t* interval. $DPIN^i_{buy_t}$ is the buying component, defined as the number of buy transactions divided by the total number of trades for group *i* in interval *t*, written as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t \right] (\varepsilon_t < 0)$, and $DPIN^i_{sell_t}$ is the selling component, defined as the number of sell transactions divided by the total number of trades of trades for group *i* in interval *t*, written as $DPIN_{sell_t} = \left[NS^i_t / NT^i_t \right] (\varepsilon_t > 0)$. The TIB measure is computed using buy and sell trades for group *i* in interval *t*, written as $TIB^i_t = (B^i_t - S^i_t) / (B^i_t + S^i_t)$.

2.2.2 The relation between volatility and trading activity

Next, our paper examines the association between volatility and trading activity. A natural question is whether volatility is significantly affected by the DPIN or the TIB. We regress the volatility on the DPIN and absolute of the TIB, and see whether the trading activities of foreign institutional investors and domestic institutional investors have an impact on market volatility. The regression models are shown as follows.

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \theta_k DPIN_{t-k}^{i} + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \, , \tag{6}$$

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \rho_k \left| TIB_{t-k}^{i} \right| + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \, , \tag{7}$$

where Vol_t denotes the volatility of index futures for the t interval. The $DPIN_t^i$ and the TIB_t^i are defined as in Equation (2) and Equation (3), respectively.

2.3 DPIN and TIB statistics

Table 1 reports the intraday DPIN and TIB of foreign institutional investors and domestic institutional investors from 2003 to 2007 in Panel A and Panel B, respectively. The DPIN is also displayed as the buy side DPIN ($DPIN_{buy}$) and the sell side DPIN ($DPIN_{sell}$). Statistics for all the measures are calculated as the daily average of all 15-minute intervals. As reported in Panel A, the means of DPIN, $DPIN_{buy}$, $DPIN_{sell}$, and TIB for foreign institutional investors are 0.4979, 0.2432, 0.2547, and

-0.0085, respectively, while the statistics for domestic institutional investors in Panel B are 0.4993, 0.2435, 0.2557, and -0.0119, respectively. The results present no significant differences between the two types of institutional investors.

We further report the correlation coefficients among variables for foreign institutional investors and domestic institutional investors in Panel C and Panel D, respectively. For foreign institutional investors, $DPIN_{buy}$ is significantly negatively correlated with returns (-0.68%), whereas $DPIN_{sell}$ is significantly positively correlated with returns (0.65%). For domestic institutional investors, $DPIN_{buy}$ is significantly negatively correlated with returns (-0.78%), whereas $DPIN_{sell}$ is significantly positively correlated with returns (0.78%). Overall, the correlation among variables is consistent with the theoretical presumption that DPIN captures buy (sell) trades in the presence of negative (positive) unexpected returns. In addition, the TIB is negatively correlated with returns for foreign institutions and positively correlated with returns for domestic institutions; the TIB is also negatively correlated with volatility for foreign institutions and positively correlated with volatility for domestic institutions. However, none of the coefficients are significant (weak to minimal). In sum, the DPIN rather than the TIB presents a much stronger association with market prices, which may imply that the DPIN is a superior proxy for price information.

[Insert Table 1 about here]

3. EMPIRICAL RESULTS

3.1 Trading activity of foreign institutional investors

Further to earlier findings, we examine the trading activity of foreign institutional investors using the DPIN and the TIB in this section. First, we study the return predictability of foreign institutional trades. The results are presented in Table 2. As reported, the coefficient of $DPIN_{buy_{t-1}}$ is significantly positive in Model (1), and remains significantly positive when controlling for other lagged DPINs. In contrast, although TIB_{t-1} is significantly positively related to market returns, it loses its significance when other lagged TIBs are included in the regression. In sum, the results indicate that the DPIN seems to be a better measure of the trading activity of foreign institutional investors than the TIB in terms of capturing their price information. This finding is consistent with Barber and Odean's (2011) argument that informed institutional investors tend to be contrarians.

[Insert Table 2 about here]

Similar to Table 2, Table 3 studies the volatility information of foreign institutional trades. We find that both $DPIN_{t-1}$ and $|TIB_{t-1}|$ are significantly related to current market volatility regardless of whether or not the other lagged DPINs and TIBs are included. In addition, all model specifications present very similar regression power, which suggests that the DPIN of foreign institutions provide information content no different to that obtained from the TIB in predicting market volatility. Interestingly, as the coefficient of $DPIN_{t-1}$ is negative, the result is consistent with Brennan and Cao (1996), which suggests that investors who adopt contrarian strategies are likely to be informed. Similarly, Avramov et al. (2006) show that informed traders generally reduce volatility by contrarian trading.

[Insert Table 3 about here]

3.2 Trading activity of foreign institutional investors during intense trading intervals

A central prediction of traditional microstructure theory is that trading takes place because investors have different beliefs or because of differences in information. The role of the number of trades in price formation is also highlighted by Easley and O'Hara (1992), who show that the presence or absence of trades may provide information to market participants. Specifically, the larger the number of trades, the higher the probability that new information has been obtained. Therefore, we also test whether the foreign institutional trades provide different information on returns during intense trading intervals. We impose additional dummies on Equations (4) and (5) to account for intense trading intervals within a day. The regression model is as follows:

$$R_t = \alpha_0 + \sum_{k=1}^{4} \delta_k DPIN^i_{buy_{t-k}} (LT_t^{i,buy}) + \sum_{k=1}^{4} \eta_k DPIN^i_{sell_{t-k}} (LT_t^{i,sell}) + \sum_{k=1}^{4} \beta_k R_{t,k} + \varepsilon_t \,, \qquad (8)$$

$$R_t = \alpha_0 + \sum_{k=1}^{4} \gamma_k TIB_{t-k}^{i} (LT_t^i) + \sum_{k=1}^{4} \beta_k R_{t-k} + \varepsilon_t \ , \qquad (9)$$

where $LT_t^{i,buy} (LT_t^{i,sell})$ is the "intense trading" indicator, equal to 1 if the value of $DPIN_{buy_t}^{i} (DPIN_{sell_t}^{i})$ and TIB_t^i are ranked as the top 10% on that day, and zero otherwise.

Table 4 reports the regression results for Equations (8) and (9). Again, we find that the coefficient of $\text{DPIN}_{\text{buy}_{t-1}}$ is significantly positive for Models (1) and (2), which is consistent with the findings reported in Table 2. However, for two models we find no evidence that *TIBs* during intense intervals are able to predict current returns. In sum, regarding the prediction of returns, the results in Table 4 show that DPINs rather than TIBs are more likely to be superior as measurements in capturing information advantageous to foreign institutional investors when trades are clustered.

[Insert Table 4 about here]

Similarly, we further estimate the following modified regression models for market volatility based on Equations (6) and (7):

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \theta_k DPIN_{t-k}^{i} (LT_t^i) + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \, , \qquad (10)$$

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \rho_k \left| TIB_{t-k}^{i} \right| (LT_t^i) + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \, , \qquad (11)$$

where all variables are defined as in previous equations. Table 5 presents the results.

Consistent with the results reported in Table 3, both DPIN_{t-1} and $\left|\text{TIB}_{t-1}\right|$ are significantly related to current market volatility during intense trading sessions regardless of whether or not the other lagged DPINs and TIBs are included. In addition, $DPIN_{t-2}$ also has a significant impact on volatilities, whereas $|TIB_{t-2}|$ presents insignificant impact. However, comparing the explanatory power, there is little difference between DPINs and TIBs. Interestingly, while the results in Table 3 show that both DPIN and TIB have a negative impact on market volatility, the results of Table 5 are the opposite. Both $DPIN_{t-1}$ and $|TIB_{t-1}|$ have a positive impact on volatility.

Extensive evidence indicates that trading volume and return volatility are positively correlated (Karpoff, 1987; Gallant, Rossi and Tauchen, 1992).[13] Jones, Kaul and Lipson (1994) find that only trade frequency affects price volatility. On the other hand, the larger the number of trades, the higher the probability that new information has been acquired (Kyle 1985). French and Roll's (1986) price formation theory also points out that price variation is caused by the provision of information. Therefore, the positive association between volatility and the DPIN or the TIB during intense trading intervals shown in Table 5 might be evidence that informed trading causes price volatility. As our earlier findings have shown, informed trading can also reduce volatility, and thus it is likely that the informed trading of foreign institutional

[13] Gallant et al. (1992) find a positive correlation between conditional volatility and volume, wherein large price movements are followed by high volumes.

investors has a twofold impact on volatility, and appears as an asymmetric influence for normal trading intervals and intense trading intervals.

[Insert Table 5 about here]

Overall, the examination of intense trading intervals using the DPIN and the TIB provides support for our earlier findings. Measuring the trading activity of foreign institutional investors through the DPIN offers a better ability to capture their information advantage regarding market returns.

3.3 Trading activity of domestic institutional investors

So far, our analyses have focused on the trading activity of foreign institutional investors, and the findings show that the DPIN performs better than the TIB in representing informed trading. For comparison, we extend the tests to domestic institutional investors. We examine their trading activity using the DPIN and the TIB as in the analyses completed in Sections 3.1 and 3.2.

Table 6 presents the relation between returns and trading activity for domestic institutional investors. Unlike the results reported in Table 2, we find that the DPIN for domestic institutional investors does not have a significant impact on market returns, whereas the TIB has a significant impact on returns in each model specification. The findings in Table 6 are not consistent with those in Table 2, indicating that the TIB is more suited to measuring return information for domestic institutional trades than the DPIN. The finding also implies that domestic institutional investors are less likely to behave as contrarian traders compared to foreign institutional traders.

[Insert Table 6 about here]

Table 7 presents the relation between volatility and trading activity for domestic institutional investors. Consistent with the findings for foreign institutional investors in Table 3, the result shows that both the DPIN and the TIB have a significant negative impact on volatility in each model specification. Again, the results confirm that the DPIN and the TIB are no different in measuring the volatility information of institutional investors.

[Insert Table 7 about here]

3.4 Trading activity of domestic institutional investors during intense trading intervals

The analyses using trades during intense trading intervals are also applied for domestic institutional investors. We rerun the regression models (Equations (8) to (11)) for the DPIN and the TIB of domestic institutional investors. First, Table 8 reports the results of the impact on returns. Interestingly, in contrast to the finding in Table 6 showing that the DPIN of domestic institutional investors has inferior ability in showing the impact on returns, the coefficient of $\mathrm{DPIN}_{\mathrm{buy}_{t-1}}$ for domestic institutional investors in Table 8 is significant, whereas that of TIB_{t-1} is insignificant. Therefore, Table 8 shows that the DPIN is still a more suitable measure for capturing the trading activity of domestic institutional investors during intense trading intervals, as shown also for foreign institutional investors.

[Insert Table 8 about here]

Finally, Table 9 reports the results of regressing volatility with the trading activity of domestic institutional investors during intense trading intervals. It is no surprise that the findings show that both the DPIN and the TIB have significant impacts on market volatility. However, in contrast to what we have shown for the DPIN and the TIB in relation to foreign institutional investors, the DPIN and the TIB for domestic institutional investors have the opposite effects. The DPIN has a positive impact on volatility, whereas the TIB has a negative impact on volatility. The results are not altered by including other lagged DPINs or TIBs.

[Insert Table 9 about here]

3.5 Discussion

Although there is slight divergence in our findings regarding the validity of the DPIN for foreign institutional investors and domestic institutional investors, it still appears that the DPIN performs considerably better in capturing informed trades in a range of situations than the TIB. The DPINs of foreign institutional investors have more significant impact on returns than TIBs in all trading sessions and intense trading intervals, and the DPINs of domestic institutional investors also have more significant impact on returns than TIBs in intense trading sessions. For volatility information, it seems that the DPIN and the TIB present no distinct difference in terms of the volatility effect. However, it is still apparent that the DPIN has more consistent impact on market volatility than the TIB. Overall, the findings indicate the suitability of the DPIN as a measure to proxy for informed trading, especially when we are interested in foreign institutional traders. In addition, the results imply that informed foreign institutional traders generally behave as contrarians, as in the setting of Chang et al. (2014) and as argued by Barber and Odean (2011).

4. CONCLUSIONS

This study examines the validity of the DPIN developed by Chang et al. (2014). Using the trades of foreign institutional investors and domestic institutional investors on the TAIFEX, we study the impact of the DPIN on market returns and volatilities and compare its effect to that of the TIB. We show that the DPIN carries more return information than the TIB, especially for foreign institutional investors. This finding suggests that the DPIN is able to capture the informed trading of foreign institutional traders. Furthermore, the DPIN as the informed trading measure provides stable performance throughout different trading intervals within a day. Compared to the traditional informed trading measure, i.e., the PIN, Chang et al.'s (2014) DPIN is a newly developed measure that provides intuitive explanation and friendly application without complex estimation. Our findings confirm its feasibility. We also believe that it is a suitable alternative approach to discern directly the intraday information content of transactions.

In addition, according to the assumption underpinning the construction of the DPIN, informed traders are more likely to behave as contrarians; thus, our results also suggest that informed foreign institutional investors generally behave as contrarians. A similar argument can be seen in Barber and Odean (2011), who claim that the informed trader has more incentives to act against price moves.

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Table 1 Characteristics of intraday trade volume measure

Panel A and Panel B of Table 1 report interval means and medians for the DPIN and TIB of institutional investors. Panel C and Panel D show correlations among all regression variables. Samples Panel A reports foreign institutional investor values and Panel B the domestic institutional investor values. *Return* denotes the index return, computed from the difference of the natural log of the mid-point of the bid–ask spread at the end of an intraday interval. *Volatility* is the GARCH(1,1) model developed by Bollerslev (1986), incorporating commonly used volatility measures. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB_t / NT_t\right](\varepsilon_t < 0)$, and $DPIN^i_{sell_t} = \left[NS_t / NT_t\right](\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t)/(B^i_t + S^i_t)$ for interval *t*. The data are from January 1, 2003 to December 31, 2007, covering 1,238 trading days.

Panel A Summary statistics for foreign institutional investors

	Mean	Std. Dev.	Skewness	Kurtosis	Obs.
DPIN	0.4979	0.3999	0.0214	1.3739	19740
$DPIN_{buy}$	0.2432	0.3734	1.1784	2.6972	19740
$DPIN_{sell}$	0.2547	0.3800	1.0823	2.4562	19740
TIB	-0.0085	0.7998	0.0390	1.3748	19740

Panel B Summary statistics for domestic institutional investors

	Mean	Std. Dev.	Skewness	Kurtosis	Obs.
DPIN	0.4993	0.2213	0.0624	2.3935	24710
$DPIN_{buy}$	0.2435	0.2909	0.7551	2.1995	24710
$DPIN_{sell}$	0.2557	0.2982	0.7045	2.1122	24710
TIB	-0.0119	0.4424	0.0080	2.3927	24710

(Continued)

Panel C Correlations for foreign institutional investors

	Return	*Volatility*	*DPIN*	$DPIN_{buy}$	$DPIN_{sell}$	*TIB*
Return	1					
Volatility	-0.0129	1				
DPIN	-0.0077	-0.0069	1			
$DPIN_{buy}$	-0.6812	0.0238	0.4084	1		
$DPIN_{sell}$	0.6548	0.0216	0.4413	-0.5992	1	
TIB	-0.0051	-0.0291	-0.0200	0.4093	-0.4394	1

Panel D Correlations for domestic institutional investors

	Return	*Volatility*	*DPIN*	$DPIN_{buy}$	$DPIN_{sell}$	*TIB*
Return	1					
Volatility	-0.0112	1				
DPIN	0.0196	-0.0654	1			
$DPIN_{buy}$	-0.7826	0.0121	0.2422	1		
$DPIN_{sell}$	0.7773	-0.0393	0.3036	-0.8481	1	
TIB	0.0316	0.0368	-0.0224	0.2571	-0.2714	1

Table 2 Intraday trade volume measure for the influence of foreign institutional investors on returns

This table presents the results with Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with index future returns as the dependent variable. R_t denotes the index futures return for the *t* interval. $DPIN_t^i$ is the number of buy transactions divided by the total number of trades for group *i* institutional investors in interval *t*. DPIN measure is computed as $DPIN_{buy_t}^i = \left[NB_t^i / NT_t^i \right] (\varepsilon_t < 0)$. $DPIN_{sell_t}^i$ is the number of sell transactions divided by the total number of trades for group *i* institutional investors in interval *t*, computed as $DPIN_{sell_t} = \left[NS_t^i / NT_t^i \right] (\varepsilon_t > 0)$. The TIB measure is computed as $TIB_t^i = (B_t^i - S_t^i) / (B_t^i + S_t^i)$ for interval *t*. The regression model is as follows:

$$R_t = \alpha_0 + \sum_{k=1}^{4} \delta_k DPIN_{buy_{t-k}}^i + \sum_{k=1}^{4} \eta_k DPIN_{sell_{t-k}}^i + \sum_{k=1}^{4} \beta_k R_{t,k} + \varepsilon_t \,, \tag{4}$$

$$R_t = \alpha_0 + \sum_{k=1}^{4} \gamma_k TIB_{t-k}^i + \sum_{k=1}^{4} \beta_k R_{t-k} + \varepsilon_t \,, \tag{5}$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{buy_{t-1}}$	$DPIN_{sell_{t-1}}$	$DPIN_{buy_{t-2}}$	$DPIN_{sell_{t-2}}$	$DPIN_{buy_{t-3}}$	$DPIN_{sell_{t-3}}$	$DPIN_{buy_{t-4}}$	$DPIN_{sell_{t-4}}$	$Adj-R^2$	Obs.
(1)	-0.0008	0.4851 ***	-0.0411							0.0013	19739
	(-0.0087)	(2.7743)	(-0.2740)								
(2)	-0.3761	0.4011*	0.0160	0.3025	0.4516 **	0.4322 **	0.4052*	0.1064	-0.2265	0.0019	19739
	(-1.9157)	(1.6843)	(0.0823)	(1.5740)	(2.0107)	(1.9961)	(1.7973)	(0.4665)	(-1.0867)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.1081	0.1170 *				0.0012	19739
	(1.6027)	(1.8270)					
(4)	0.0892	-0.1259	-0.1753	0.3230 **	0.3308***	0.0024	19739
	(1.1132)	(-1.0315)	(-1.3279)	(2.5316)	(2.6211)		

Table 3 Intraday trade volume measure for the influence of foreign institutional investors on volatility

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with the volatility of index futures as the dependent variable. Vol_t is the GARCH(1,1) model developed by Bollerslev (1986), incorporating commonly used volatility measures. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t \right](\varepsilon_t < 0)$, and $DPIN^i_{sell_t} = \left[NS^i_t / NT^i_t \right](\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t)/(B^i_t + S^i_t)$ for interval *t*. The regression model is as follows:

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \theta_k DPIN^i_{t-k} + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \,, \qquad (6)$$

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \rho_k \left| TIB^i_{t-k} \right| + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \,, \qquad (7)$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{t-1}$	$DPIN_{t-2}$	$DPIN_{t-3}$	$DPIN_{t-4}$	$Adj-R^2$	Obs.
(1)	0.0192 ***	-0.0048 ***				0.5684	19739
	(26.6551)	(-7.8454)					
(2)	0.0195 ***	-0.0054 ***	-0.0011	-0.0003	0.0026 ***	0.5616	19739
	(16.2112)	(-6.6164)	-(1.4722)	(-0.5063)	(4.4138)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.0221***	-0.0068 ***				0.5686	19739
	(20.5824)	(-6.9445)					
(4)	0.0265***	-0.0038 ***	-0.0025 **	-0.0050 ***	-0.0008	0.5622	19739
	(15.2654)	(-4.1442)	(-2.0392)	(-3.3533)	-(0.9142)		

Table 4 Intraday trade volume measure for the influence of foreign institutional investors on returns, conditioned on the intense trading interval

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with the returns of index futures as the dependent variable. R_t denotes the index futures return in the *t* interval. $DPIN^i_{buy_t}$ is number of buy transactions divided by the total number of trades for group *i* institutional investors in interval *t*. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t \right] (\varepsilon_t < 0)$. $DPIN^i_{sell_t}$ is the number of sell transactions divided by the total number of trades for group *i* institutional investors in interval *t*, as $DPIN_{sell_t} = \left[NS^i_t / NT^i_t \right] (\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t)/(B^i_t + S^i_t)$ for interval *t*. $LT^{i,buy}_t (LT^{i,sell}_t)$ is a "large trades" indicator variable that equals 1 if $DPIN^i_{buy_t}$ ($DPIN^i_{sell_t}$) and TIB^i_t were located in the top 10% of the current day, and zero otherwise. The regression model is as follows:

$$R_t = \alpha_0 + \sum_{k=1}^{4} \delta_k DPIN^i_{buy_{t-k}} (LT^{i,buy}_t) + \sum_{k=1}^{4} \eta_k DPIN^i_{sell_{t-k}} (LT^{i,sell}_t) + \sum_{k=1}^{4} \beta_k R_{t,k} + \varepsilon_t \ , \quad (8)$$

$$R_t = \alpha_0 + \sum_{k=1}^{4} \gamma_k TIB^i_{t-k} (LT^i_t) + \sum_{k=1}^{4} \beta_k R_{t-k} + \varepsilon_t \ , \quad (9)$$

***indicates significance at the 1%level; **indicates significance at the 5%level; and *indicates significance at the 10%level.

	Intercept	$DPIN_{buy_{t-1}}$	$DPIN_{sell_{t-1}}$	$DPIN_{buy_{t-2}}$	$DPIN_{sell_{t-2}}$	$DPIN_{buy_{t-3}}$	$DPIN_{sell_{t-3}}$	$DPIN_{buy_{t-4}}$	$DPIN_{sell_{t-4}}$	$Adj-R^2$	Obs.
(1)	0.0464	1.6121 ***	0.1264							0.0015	19739
	(0.6504)	(3.0167)	(0.3257)								
(2)	0.0592	1.8392 ***	0.1719	-0.1043	-1.2580**	0.1893	-0.1852	0.1431	0.1461	0.0022	19739
	(0.6242)	(2.6893)	(0.3508)	(-0.2474)	(-1.9768)	(0.3772)	(-0.3689)	(0.3434)	(0.3097)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.1159*	-0.3025				0.0012	19739
	(1.6833)	(-0.6043)					
(4)	0.1225	-0.2803	-0.7218	0.1976	-0.1913	0.0019	19739
	(1.4949)	(-0.5277)	(-1.3877)	(0.3703)	(-0.3323)		

Table 5 Intraday trade volume measure for the influence of foreign institutional investors on volatility, conditioned on the intense trading interval

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with the volatility of index futures as the dependent variable. Vol_t is the GARCH(1,1) model developed by Bollerslev (1986), incorporating commonly used volatility measures. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t \right](\varepsilon_t < 0)$, and $DPIN^i_{sell_t} = \left[NS^i_t / NT^i_t \right](\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t)/(B^i_t + S^i_t)$ for interval *t*. (LT^i_t) is a "large trades" indicator variable that equals 1 if $DPIN^i_t$ (TIB^i_t) was located in the top 10% of the current day, and zero otherwise. The regression model is as follows:

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \theta_k DPIN^i_{t-k}(LT^i_t) + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \, , \qquad (10)$$

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \rho_k \left| TIB^i_{t-k} \right| (LT^i_t) + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t \, , \qquad (11)$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{t-1}$	$DPIN_{t-2}$	$DPIN_{t-3}$	$DPIN_{t-4}$	$Adj-R^2$	Obs.
(1)	0.0163 ***	0.0122 ***				0.5687	19739
	(26.7186)	(7.4349)					
(2)	0.0165 ***	0.0141 ***	0.0092 ***	0.0013	-0.0027	0.5624	19739
	(25.3577)	(7.2770)	(4.9267)	(0.4951)	(-1.4875)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.0167 ***	0.0063 ***				0.5680	19739
	(26.2762)	(3.2396)					
(4)	0.0173 ***	0.0061 ***	0.0001	-0.0001	-0.0004	0.5610	19739
	(23.7398)	(2.9091)	(0.0905)	(-0.0704)	(-0.2691)		

Table 6 Intraday trade volume measure for the influence of domestic institutional investors on returns

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with index future returns as the dependent variable. R_t denotes the index futures return in the *t* interval. $DPIN^i_{buy_t}$ is number of buy transactions divided by the total number of trades for group *i* institutional investors in interval *t*. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t \right] (\varepsilon_t < 0)$. $DPIN^i_{sell_t}$ is number of sell transactions divided by the total number of trades for group *i* institutional investors in interval *t*, computed as $DPIN_{sell_t} = \left[NS^i_t / NT^i_t \right] (\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t) / (B^i_t + S^i_t)$ for interval *t*. The regression model is as follows:

$$R_t = \alpha_0 + \sum_{k=1}^{4} \delta_k DPIN^i_{buy_{t-k}} + \sum_{k=1}^{4} \eta_k DPIN^i_{sell_{t-k}} + \sum_{k=1}^{4} \beta_k R_{t,k} + \varepsilon_t \ , \quad (4)$$

$$R_t = \alpha_0 + \sum_{k=1}^{4} \gamma_k TIB^i_{t-k} + \sum_{k=1}^{4} \beta_k R_{t-k} + \varepsilon_t \ , \quad (5)$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{buy_{t-1}}$	$DPIN_{sell_{t-1}}$	$DPIN_{buy_{t-2}}$	$DPIN_{sell_{t-2}}$	$DPIN_{buy_{t-3}}$	$DPIN_{sell_{t-3}}$	$DPIN_{buy_{t-4}}$	$DPIN_{sell_{t-4}}$	$Adj-R^2$	Obs.
(1)	0.1843	0.4174	-0.5131							0.0012	24706
	(0.9408)	(1.0650)	(-1.3337)								
(2)	-0.2294	0.3996	-0.5421	0.2692	-0.0009	0.5812	0.8608 **	-0.1038	0.0906	0.0011	24706
	(-0.5853)	(1.0017)	(-1.3606)	(0.5789)	(-0.0021)	(1.3263)	(2.1489)	(-0.2428)	(0.2215)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.1651 *	0.6957 ***				0.0015	24706
	(1.8451)	(3.6789)					
(4)	0.1680 *	0.5404 ***	0.1021	0.3036	0.0442	0.0015	24706
	(1.8924)	(2.6572)	(0.4847)	(1.3284)	(0.2081)		

Table 7 Intraday trade volume measure for the influence of domestic institutional investors on volatility

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with the volatility of index futures as the dependent variable. Vol_t is the GARCH(1,1) model developed by Bollerslev (1986), incorporating commonly used volatility measures. The DPIN measure is computed as $DPIN^{i}_{buy_t} = \left[NB^{i}_{t} / NT^{i}_{t} \right] (\varepsilon_t < 0)$, and $DPIN^{i}_{sell_t} = \left[NS^{i}_{t} / NT^{i}_{t} \right] (\varepsilon_t > 0)$. The TIB measure is computed as $TIB^{i}_{t} = (B^{i}_{t} - S^{i}_{t}) / (B^{i}_{t} + S^{i}_{t})$ for interval *t*. The regression model is as follows:

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \theta_k DPIN^{i}_{t-k} + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t , \quad (6)$$

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \rho_k \left| TIB^{i}_{t-k} \right| + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t , \quad (7)$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{t-1}$	$DPIN_{t-2}$	$DPIN_{t-3}$	$DPIN_{t-4}$	$Adj-R^2$	Obs.
(1)	0.0228 ***	-0.0137 ***				0.5781	24706
	(18.7043)	(-8.3619)					
(2)	0.0261 ***	-0.0137 ***	-0.0021*	-0.0017	-0.0027**	0.5780	24706
	(13.3868)	(-8.8208)	(-1.8448)	(-1.2151)	(-2.1373)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.0183 ***	-0.0061 ***				0.5768	24706
	(19.4856)	(-6.1530)					
(4)	0.0201 ***	-0.0050 ***	-0.0030**	0.0004	-0.0029 ***	0.5767	24706
	(15.9852)	(-5.0343)	(-2.2722)	(0.3498)	(-2.7861)		

Table 8 Intraday trade volume measure for the influence of domestic institutional investors on return, conditioned on the intense trading interval

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with the return of index futures as the dependent variable. R_t denotes the index futures return in the *t* interval. $DPIN^i$ is number of buy transactions divided by the total number of trades for group *i* institutional investors in interval *t*. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t \right](\varepsilon_t < 0)$. $DPIN^i_{sell_t}$ is the number of sell transactions divided by the total number of trades for group *i* institutional investors in interval *t*, computed as $DPIN_{sell_t} = \left[NS^i_t / NT^i_t \right](\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t) / (B^i_t + S^i_t)$ for interval *t*. $LT^{i,buy}_t (LT^{i,sell}_t)$ is a "large trades" indicator variable that equals 1 if $DPIN^i_{buy_t}$ ($DPIN^i_{sell_t}$) and TIB^i_t were located in the top 10% of the current day, and zero otherwise. The regression model is as follows:

$$R_t = \alpha_0 + \sum_{k=1}^{4} \delta_k DPIN^i_{buy_{t-k}} (LT^{i,buy}_t) + \sum_{k=1}^{4} \eta_k DPIN^i_{sell_{t-k}} (LT^{i,sell}_t) + \sum_{k=1}^{4} \beta_k R_{t,k} + \varepsilon_t \ , \quad (8)$$

$$R_t = \alpha_0 + \sum_{k=1}^{4} \gamma_k TIB^i_{t-k} (LT^i_t) + \sum_{k=1}^{4} \beta_k R_{t-k} + \varepsilon_t \ , \quad (9)$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{buy_{t-1}}$	$DPIN_{sell_{t-1}}$	$DPIN_{buy_{t-2}}$	$DPIN_{sell_{t-2}}$	$DPIN_{buy_{t-3}}$	$DPIN_{sell_{t-3}}$	$DPIN_{buy_{t-4}}$	$DPIN_{sell_{t-4}}$	$Adj-R^2$	Obs.
(1)	0.0951	2.0555**	0.1881							0.0013	24706
	(0.9478)	(2.5352)	(0.2150)								
(2)	0.0905	2.0638**	0.1842	-0.5050	-0.4740	0.4542	0.7701	-0.1181	-0.0033	0.0011	24706
	(0.8475)	(2.5251)	(0.2092)	(-0.5739)	(-0.6493)	(0.6855)	(1.2671)	(-0.1753)	(-0.0049)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.1281	0.4951				0.0010	24706
	(1.3400)	(1.2932)					
(4)	0.1325	0.5075	-0.3586	0.4050	-0.1544	0.0010	24706
	(1.2951)	(1.3303)	(-0.8288)	(0.9621)	(-0.3117)		

Table 9 Intraday trade volume measure for the influence of domestic institutional investors on volatility, conditioned on the intense trading interval

This table presents the results of the Newey–West corrected *t*-statistics for time-series regressions from January 1, 2003 to December 31, 2007 with the volatility of index futures as the dependent variable. Vol_t is the GARCH(1,1) model developed by Bollerslev (1986), incorporating commonly used volatility measures. The DPIN measure is computed as $DPIN^i_{buy_t} = \left[NB^i_t / NT^i_t\right](\varepsilon_t < 0)$, and $DPIN^i_{sell_t} = \left[NS^i_t / NT^i_t\right](\varepsilon_t > 0)$. The TIB measure is computed as $TIB^i_t = (B^i_t - S^i_t)/(B^i_t + S^i_t)$ for interval *t*. (LT^i_t) is a "large trades" indicator variable that equals 1 if $DPIN^i_t$ (TIB^i_t) was located in the top 10% of the current day, and zero otherwise. The regression model is as follows:

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \theta_k DPIN^i_{t-k}(LT^i_t) + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t , \quad (10)$$

$$Vol_t = \alpha_0 + \sum_{k=1}^{4} \rho_k \left|TIB^i_{t-k}\right|(LT^i_t) + \sum_{k=1}^{4} \lambda_k Vol_{t-k} + \varepsilon_t , \quad (11)$$

***indicates significance at the 1% level; **indicates significance at the 5% level; *indicates significance at the 10% level.

	Intercept	$DPIN_{t-1}$	$DPIN_{t-2}$	$DPIN_{t-3}$	$DPIN_{t-4}$	$Adj-R^2$	Obs.
(1)	0.0144 ***	0.0455 ***				0.5844	24706
	(20.2767)	(11.1331)					
(2)	0.01493 ***	0.0456 ***	-0.0053	-0.0091	-0.0099	0.5850	24706
	(21.1546)	(11.1214)	(-2.1330)	(-6.5553)	(-4.4407)		

	Intercept	TIB_{t-1}	TIB_{t-2}	TIB_{t-3}	TIB_{t-4}	$Adj-R^2$	Obs.
(3)	0.0161 ***	-0.0028 ***				0.5764	24706
	(20.1711)	(-2.4684)					
(4)	0.0161 ***	-0.0027 **	-0.0024 **	-0.0001	0.0022	0.5762	24706
	(19.8654)	(-2.3699)	(-2.2311)	(-0.0811)	(1.2994)		