Investor Behavior towards Trading Derivative Warrants and Underlying Assets in the Stock Exchange of Thailand

Pongsaton Promto[1*] ,Ravi Lonkani[2] and Tanachote Boonvorachote[3]

[1*,2]Faculty of Business Administration, Chiang Mai University

[3]Faculty of Agro-Industry, Kasetsart University

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Abstract

Derivative warrant order imbalance causes market makers to hedge their inventory risk by purchasing the underlying stock at delta quantities. As a result, the information on the derivative warrant trading imbalance transmits to the underlying stock. To study the effect of information, this research has divided the trading imbalance into the order imbalance of derivative warrants and the order imbalance of underlying assets. The result shows that derivative warrants order imbalance can carry information to the underlying stock and causes the underlying price readjustment in the next day. However, the underlying asset order imbalance reveals only the effect of price pressure. When analyzing the intraday transaction, the derivative warrants show a positive correlation to the underlying asset return over the next 30 minutes of any interval. Thus, this research concludes that the derivative warrants trading comprised of informative trading which reduces the information asymmetry.

Keywords: 1) Order Imbalance 2) Derivative warrant 3) Informed traders

[1*] Master student, Department of Science in Finance; E-mail: p.promto@gmail.com (Corresponding Author)

[2] Associate Professor, Department of Finance; E-mail: ravi.l@cmu.ac.th

[3] Associate Professor, Agro-Industrial Technology Department; E-mail: tanachote.b@ku.ac.th

Introduction

A derivative warrant, like an option, is a derivative instrument. However, there are 4 significant differences. 1) Derivative warrants are traded in the same market as underlying securities which have a high trading volume and are more accessible than options. 2) A market maker handles the buying and selling of derivative warrants. 3) Due to the exercise ratio, derivative warrants are more inexpensive than options. 4) In Thailand, options have a single underlying asset, the SET50, whereas derivative warrants have more variety. The above distinctions imply that derivative warrants are an appealing investment, particularly for informed traders who benefit from extraneous information, because the risks are limited and the returns are higher than direct investments in underlying assets (Black, 1975, pp. 39-40). The preceding statements are consistent with previous works (Pan and Poteshman, 2006, p.872; Chang, Hsieh and Lai 2009, p.763; Roll, Schwartz and Subrahmanyam, 2010, p.2 ; Hu, 2014, p.625) stating that when informed investors trade in the options market, the information about the true price of the underlying asset is transmitted to the market. Correspondingly, the options market correlates with the underlying stock's future price movement, resulting in price discovery because informed trading reduces price volatility (Avramov, Chordia and Goyal, 2006, p.2393).

As a result, options trading can help reduce information asymmetry, resulting in a lower cost of equity and a higher company value (Blanco and Garcia, 2021, p.2).

One of the key factors in utilizing certain knowledge for informed investors is the liquidity of underlying assets and options (Easley, O'Hara, and Srinivas,1998, pp. 463-464). This study employed derivative warrants to investigate and test the impact of information from informed investors' trading behavior on underlying asset price changes. The method involved gathering information derived from derivative warrant transactions with the same underlying asset but different issuers, exercise prices, and instrument terms. Based on Holowczak, Hu, and Wu (2014, pp. 9-21) and Hu (2014, pp. 628-629), this research assumes that the market maker will hedge when the derivative warrants trading volume is imbalance (order imbalance) to reduce inventory risk. Because delta hedging using Black and Scholes' method (1973, p.644) cannot immediately readjust the purchase volume by acquiring the underlying asset, information from derivative warrants flows to the underlying stocks. To better understand the relationship between underlying securities and derivative warrants, this paper divides the stock order imbalance (SOI) into derivative warrant order imbalance (DWOI) and net stock order imbalance (nSOI) which is unrelated to the derivative warrants. The data is then analyzed on a daily and intraday basis.

Literature Review

Information Effect

In the study of information asymmetrical, there are two types of traders: the uninformed and the informed. The uninformed are the market makers who manage derivatives orders and general investors trading for liquidity-based reasons. The informed trader,

on the other hand, will trade until the effects of information wear off. According to Easley and O'hara (1987, p.70), informed investors prefer larger trade size and will try to match the normal price to disguise themselves as uninformed traders and conceal their trades. Furthermore, Garvey (2017, p.256) asserted that large trade sizes have a greater informational effect than small trade sizes. Controlling the order time shows that small orders are more influenced by information because informed investors will split their orders to cover their information exploitation. Black (1975, pp.39-40) stated that the options market is the most appealing choice for informed investors. When compared to direct investment in underlying assets, the leverage effect provides the highest returns while using fewer funds and poses the least risk. As a result, informed traders investing in options will lead to price discovery and correlate with future underlying asset price movements. However, in some cases, the underlying asset's price has already changed, increasing the volume of options trading. Because informed traders opted for the information in the more liquid market. Previous studies (Pan and Poteshman, 2006, p.872; Chang, Hsieh, and Lai, 2009, p.763; Roll Schwartz and Subrahmanyam, 2010, p.2; Hu, 2014, p.625) help validate that options' order flow reveal information about the future price of the underlying asset to the market due to informed investors. Blanco and Garcia (2021, p2) pointed out that options trading help ameliorate asymmetric information, leading to a lower cost of equity. Consequently, firms make more risky managerial investment decisions, such as innovation, which increases the company's market value. Furthermore, Zhou (2022, p.2) discovered that the options market is positively related to future leverage and negatively related to the stock returns prior to the earnings announcement. These relations increase significantly in low-value, high-volatility, high-credit-risk stocks. The data presented above confirm that options trading is influenced by fundamental information about a company, causing stock prices to adjust.

Underlying Asset Order Imbalance Hypothesis

Easley and O'hara (1987, p.70) previously observed that trading volume can reveal information about asset prices. Informed traders will engage in transactions until they are unable to exploit the information they have obtained. Thus, the informative trading leads to an order imbalance. Chordia and Subrahmanyam (2004, p.509); Smales, (2012, p.411) and Narayan, Narayan and Westerlundac (2015, p.136) also dictated that order imbalance has a positive and negative association with returns rate. In other words, informational trading may cause order imbalance. This group of researchers also discovered that if the relationship is positive and generated by price pressure, the price will rebalance and reverse to a fair volume when the effect of price pressure disappears. When trying to organize the portfolio according to the stock order imbalance, we discovered that this strategy yields a higher return than the Sharpe ratio, especially in small businesses (Zhang, Jiang and Zhou , 2021, pp.2833-2834).

H_1 : order imbalance at time t - i

(i = lag value) which is correlate to return at time t

Derivative Warrant Order Imbalance Hypothesis

Black (1975, pp.39-41,62) explored into the idea that informed investors will profit from their information by trading in the options market because of the leverage effect. The traders will want to purchase (sell) if the news is good (bad). Roll, Schwartz and Subrahmanyam (2010, p.16) studied the trading behaviors in options and underlying assets markets. They discovered that the ratio of options traded to the underlying asset trading volume during the earning announcement date has a positive correlation to the rate of returns and the effect is permanent. The outcome suggests that informed traders actively participate in the options market. Excess of buy or sell orders causes imbalance and the market maker is the one bearing the risk. In order to alleviate the risk, the market makers must execute delta-hedging on their underlying stocks (Hu, 2014, p.626) which triggers order imbalance in derivative warrants. Furthermore, Gilstrap, Petkevich and Teterin (2020, p.20) discovered that insider's trading is positively correlated to an imbalance of option order. Nevertheless, the information exploitation leads their transaction to be contrarian to the firm's fundamentals during earning announcements.

H_2: Order imbalance of derivative warrant with the same underlying asset is related to the return of the underlying securities.

Market Microstructure Hypothesis

Market microstructure is comprised of the deal price, deal volume, order, investor type, securities or commodities traded including trading behavior and market environment. It is under the hypothesis that these mechanisms affect the price setting and returns rate. (Boonvorachote, 2008, pp.2-6). Hu (2014, p.636) stated that intraday options trading can notify the market about the underlying stock price. In addition, Lee and Chen (2005, p.587) discovered a positive correlation between intraday volatility of options and underlying assets. Easley, O'Hara, and Srinivas (1998, pp. 431-434) investigated the volume of options trading and the underlying price movement and discovered a positive correlation between the two in day trading. Furthermore, Tripathi, Dixit, and Vipul (2021, pp.7-8) spotted a relationship between order imbalance and rate of return in the next five to 30 minutes, signifying the effect of intraday informative trading.

H_3: Order imbalance in intraday derivative warrants can predict the return in the following time frame.

Methods

The data used in this study are derivative warrants traded on the Thai Stock Exchange from January 1, 2013, to December 31, 2017. The sample consists of 5,875 call warrants and 1,763 put warrants from 141 underlying stocks. The SET Market Microstructure Research Program data was obtained from the SETSMART and Bloomberg databases. To reduce the possibility of error in analysis, all data is collected with the exceptions of 1) derivative warrants less than 10 days old, 2) information 15 minutes before market opening and five

minutes after market closing (from 10.15 a.m. to 4:30 p.m.), 3) the stock splitting date, and 4) the date with XD and XR signs. In calculating the delta, the risk-free rate is 0 and the Black-Scholes model (1973, p.644) is utilized.

Derivative Warrant Order Imbalance: DWOI

According to Hu's research (2014, p.626) , excessive options trading causes market makers to rebalance their positions. Each derivative warrant's underlying equity will be delta hedged by the market maker. Because derivative warrant on the same underlying stock is issued by numerous firms, we calculate the DWOI with the same underlying asset as follow:

$$DWOI_{i,t} = \sum_{j=1}^{n} \frac{DR_{i,t} * Dir_{i,t,j} * delta_{i,t} * size_{i,t,j}}{number\ of\ listed\ shares_{\ i}} \quad (1)$$

For stock i on date t, $\mathbf{DR}_{i,t}$ is a number of underlying assets per one derivative warrant. $\mathbf{Dir}_{i,t,j}$ is the dummy variable with a value of 1 (-1) when j is buy (sell). $\mathbf{delta}_{i,t}$ is the sensitivity of derivative warrant price movement to underlying stock price movement. $\mathbf{size}_{i,t,j}$ is the number of derivative warrants on underlying asset I traded on date t transaction j. And $\mathbf{number\ of\ listed\ shares}_{i}$ are the listed underlying assets.

Net Stock order Imbalance: nSOI

The stock order imbalance (SOI) reflects the excess buying or selling of underlying assets, which includes the DWOI. To reduce data redundancy, referencing Hu's research (2014, p.629), we calculated the net stock order imbalance (nSOI) and separated the irrelevant SOI from the derivative warrants as follows:

$$nSOI_{i,t} = SOI_{i,t} - DWOI_{i,t}$$
$$= \sum_{j=1}^{n} \frac{Dir_{i,t,j} * size_{i,t,j}}{number\ of\ listed\ shares_{\ i}} - DWOI_{i,t} \quad (2)$$

$\mathbf{SOI}_{i,t}$ is related to the trading volume of stock i on date t. $\mathbf{Dir}_{i,t,j}$ is dummy variable with the value 1 (-1) when j is buy (sell). $\mathbf{size}_{i,t,j}$ is the number of underlying stock i traded on day t in transaction j. $\mathbf{DWOI}_{i,t}$ is the DWOI i on date t. And $\mathbf{number\ of\ listed\ shares}_{i}$ is number of listed stock i.

Tools for Measuring Profit Predictability in Underlying Asset

The order imbalance of the underlying stocks that are unrelated to the derivative warrant, as well as the order imbalance of derivative warrants are used as proxy. Then, in this paper, panel data analysis is applied to investigate the relationship between the underlying stock and the proxy. The Hausman test is used to test the random effect. It is found that all equations reject null hypothesis at significance level 0.01. We then used fixed effect regression model (FEM) according to Patel, et al., (2020, pp.4-6) to determine the actual price of the underlying stocks and options. This is done to lessen the impact of an unobserved effect. This paper does not use the Fama-Macbeth regression, in consonance with Hu's paper (2014), since the derivatives warrants with different underlying securities have different correlation analysis times and are in varieties of numbers. These different properties may produce issues such as omitted variables, which can make equations unreliable or inaccurate (Anatolyev and Mikusheva, 2022, p.105).

Equation for Studying the Relationship Between Rate of Return and daily DWOI

$$Adjusted\ Return_{i,t} = \alpha_{i,t} + \sum_{k=1}^{5} \beta_1^k nSOI_{i,t-k} + \sum_{k=1}^{5} \beta_2^k DWOI_{i,t-k} + \gamma X_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

$\mathbf{Adjusted\ Return}_{i,t}$ is the adjusted rate of return of stock i on date t using the adjusted

price of the stock n. $\mathbf{nSOI}_{i,t-k}$I is the SOI of i at date t-k. $\mathbf{DWOI}_{i,t-k}$ is the DWOI of i at date t-k. $\mathbf{X}_{i,t-1}$ is the controlled variable of stock i at date t-, which comprised of the turnover. **VolDW** is the logarithm of the derivative warrants trading volume. **VolStock** is the logarithm of volume of underlying stock i. Return is the adjusted return of stock i in the past 5 days. **DwReturn** is the average return of the derivative warrants with underlying stock i in the past 5 days. The α_i is the stock fixed effect. And λ_t is time fixed effect.

Equation for Studying the Relationship Between Rate of Return and intraday DWOI

Study on trading behavior of intraday derivatives warrants. The study will be divided into 30-minute sessiom time frame, a total of six sessions, starting from Session 1 (11.30 a.m. - 12.00 p.m.), Session 2 (12.00 - 12.30 p.m.), Session 3 (14.30 - 15.00 p.m.), Session 4 (15.00 - 15.30 p.m.), Session 5 (15.30 - 16.00 p.m.), and Session 6 (16.00 - 16.30 p.m.) using the following equation:

$$Return_{i,t} = \alpha_{i,t} + \sum_{k=1}^{2} \beta_1^k SOI_{i,t-k} + \sum_{k=1}^{2} \beta_2^k DWOI_{i,t-k} + \theta X_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t} \quad (4)$$

$\mathbf{Return}_{i,t}$ is the return of stock i at time t calculated from the last price in each n session. $\mathbf{nSOI}_{i,t-k}$ is the nSOI of i at time t-k. $\mathbf{DWOI}_{i,t-k}$ is the DWOI with underlying stock i at time t-k. $\mathbf{X}_{i,t-1}$ is the controlled variable, the market microstructure in asset i at time t-1, which is comprised of $VolDW_{t-1}$. Where $\mathbf{VolDW}_{t-1}$ is the logarithm of derivative warrants trading volume with underlying stock i at time t-1. $\mathbf{VolStock}_{t-1}$ is the logarithm of underlying stock i trading volume at time t-1. $\mathbf{Return}_{t-k}$ is the return of the underlying stock in the past two days. α_i is the stock fixed effect. λ_t is the time fixed effect.

Results

Data analysis was divided into 1) general data characteristics, 2) analysis of the nSOI and DWOI in daily underlying asset profit predictability, 3) analysis of the DWOI in intraday underlying asset profit predictability.

General Information

Table No. 1 provides the daily total derivative warrants trading volumes in each category.

Trading Volume	Mean	Std	Maximum	Minimum
Total	1,892,201,144	973,762,538	7,205,467,3002	344,549,700
Buy (call) volume	784,513,847	447,328,395	2,856,139,500	142,672,800
Buy (put) volume	173,215,194	103,130,925	911,519,800	17,220,100
Sell (call) volume	769,066,152	405,921,532	2,780,365,700	132,494,500
Sell (put) volume	165,405,952	90,007,482.71	868,527,400	20,468,400

Table No. 2 provides descriptive statistics of the daily means of the variables.

Main Variable	Mean	Std	Maximum	Minimum	Skewness	Kurtosis
Adjusted return	0.0266%	2.0763%	26.1930%	-35.5262%	-0.0862	11.2172
SOI	0.0034%	0.1813%	9.0462%	-8.2308%	3.8488	300.4598
nSOI	0.0029%	0.1752%	8.6459%	-8.2311%	3.4805	306.9340
DWOI	0.0005%	0.0195%	0.9140%	-0.4654%	4.6956	177.0654
Turnover	0.4525%	0.8149%	44.8634%	0.0002%	12.8504	390.5758
VolStock	15.4900	1.6040	21.7577	5.2983	0.1586	0.1783
VolDW	15.2587	2.3863	21.5421	4.6052	-1.0503	1.7925

Table No. 3 provides correlation between variables.

	Adjusted Return	SOI	nSOI	DWOI	Turnover	VotStock	VolDW
Adjusted Return	1.0000						
SOI	0.4124	1.0000					
nSOI	0.3983	0.9945	1.0000				
DWOI	0.2543	0.3575	0.2586	1.0000			
Turnover	0.0865	0.2155	0.2086	0.1291	1.0000		
VotStock	0.0594	0.0777	0.0756	0.0432	0.4898	1.0000	
VolDW	0.0516	0.0794	0.0767	0.0489	0.3086	0.5297	1.0000

General Information

Table No. 1 reports a daily transaction of the derivative warrants using cross check method between order data and deal data (Tanthanongsakkun, et al., 2018, p.119) and Tick Rules (Lee and Ready, 1991, pp.734-737). When determining the trading direction, it is observed that the total warrants trading volume has a daily mean at 1,892,201,144, the highest volume is 7,205,467,300 units per day and lowest is 344,549,700 units per day. Whereas, the standard deviation is 973,762,538 transaction per day. Speculating on the trading volume of each category yielded the following results: the buying and selling volume of call derivative warrants amounted to 784,513,847 and 769,066,152 units per day, respectively. Higher than the buying and selling of put warrants which are 173,215,194 and 165,405,952 units per day, respectively. The highest volume of buying call warrants is 2,856,139,500 units per day, whereas the lowest volume of purchasing put is 17,220,100 units per day. The information presented above is consistent with the number of derivative warrants trades executed, confirming that investors in the SET

prefer to trade in a call derivative warrant.

The results of data analysis in Table No. 2 reveal that the average adjusted return is 0.0266%, with a data range of 26.1930% to -35.5262%. The numbers reflect the price movements generated by transactions of investors with differing views on the stock price, the SOI, the nSOI, the DWOI, and turnover adjusted with listed stocks in percentage. The mean for the SOI, the nSOI, and the DWOI are 0.0034%, 0.0029%, and 0.0005%, respectively. The data implies that underlying stock trading is the greatest influence on the SOI. On the other side, the DWOI generate from the derivative warrants trading has a lower value due to the exercise ration. As a result, the trading of one warrant has little impact on the underlying asset trading volume. The turnover volume, which denotes total trading volume, has a mean of 0.4525%, a maximum of 44.863%, and a minimum of 0.0002%. VolStock and VolDW have post logarithm adjusted mean values of 15.4900 and 15.2587, respectively. The near value indicates that SET investors are equally interested in the derivative warrant and underlying stock trading.

Table No. 3 reports that the adjusted return has a positive correlation with all variables, indicating that trading behavior influences the price to move in the same direction. The multicollinearity shows a high correlation between the SOI and its component, the nSOI, at the value of 0.9945. The impact of such problems can be recognized when the SOI is divided into the nSOI and the DWOI. Similarly, the nSOI and DWOI have a positive correlation of 0.2543, indicating that both instruments' trading behavior has the same opinion on the underlying asset. When there is derivative warrant trading activity, a market maker will carry out that activity with the underlying asset to send information about the price movement from the warrant to the underlying stock. Simultaneously, the intraday derivative trading volume and the underlying asset has a positive correlation of 0.5297, indicating that both trading volumes move in the same direction.

Predictability of Daily Underlying Asset Returns Using nSOI and DWOI

From Table No. 4 Column 1, we found that the SOI is negatively correlated to the adjusted return at -0.1782, because investors appear to overreact to some information, causing prices to adjust in the following day. In Column 2, when extracting the previous SOI into the nSOI and DWOI, we discovered that the two elements can explain price movement. This statistic suggests that both trading activities are influenced by information that causes price changes in the underlying stocks. In Column 3, we found that the nSOI affects the price to increase from -0.12373 (t-1) to -1.6435 (t-2) at significance level 0.01. When the price finish adjusting, the only thing left is price pressure. Column 3 reveals that the nSOI causes the price to adjust higher from -0.124=373 (t-1) to -1.6435 (t-2) at significance level 0.01. Once the price has adjusted, only the effect of price pressure is left. At t-3, the nSOI has a coefficient of 0.064431 (significance level 0.01). The DWOI at t-1, on the other hand, is negatively correlated to the adjusted returns with a coefficient of -1.43362 (significance level 0.01). This

data signifies that derivatives trading has a significant impact on price movement and causes price pressure over time (t-3). After adding the controlled variable in column 4 which displays the overall test result, we observed that the nSOI only caused price pressure, not price adjustment. While the DWOI causes the underlying stock price to move the next day with a coefficient value of -0.77313 (significance level 0.01), over time, investors are still attracted to buy in the same direction after the price adjustment.

Table No. 4 The data analysis results of daily underlying stock return prediction using nSOI and DWOI

Equation for Column 1:

$$Adj\_Return_{i,t} = \alpha_{i,t} + \theta SOI_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t}$$

Equation for Column 2-4:

$$Adjusted\_Return_{i,t} = \alpha_{i,t} + \sum_{k=1}^{5} \beta_1^k nSOI_{i,t-k} + \sum_{k=1}^{5} \beta_2^k DWOI_{i,t-k} + \theta X_{i,t-1} + \alpha_i + \lambda_t + \varepsilon_{i,t}$$

$\mathbf{Adjusted\_Return}_{i,t}$ is the daily adjusted return of asset i at day t. $\mathbf{SOI}_{i,t-1}$ is the SOI of stock i at day t.;$\mathbf{nSOI}_{i,t-k}$ is the nSOI of stock i at day t-k. $\mathbf{DWOI}_{i,t-k}$ is the DWOI of stock i at day t-k. $\mathbf{X}_{i,t-1}$ is the controlled variable of stock i at day t-1 , comprised of the past five days return. DwReturn is the average return of the derivative warrant with the same underlying stock in the past five days. **VolStock** is the stock trading volume from 10.15 a.m.-16.30 p.m. **VolDW** is the derivative warrants trading volume from 10.15 a.m.-16.30 p.m α_i is the stock fixed effect. And λ_t is the time fixed effect.

Variable	(1)	(2)	(3)	(4)
Intercept	0.007877*** (3.89)	0.007905*** (3.9)	0.007914*** (3.91)	0.004137* (1.8)
SOI_{t-1}	-0.17482*** (-5.3)			
$nSOI_{t-1}$		-0.12927*** (-3.68)	-0.12373*** (-3.51)	0.050121 -1.32
$nSOI_{t-2}$			-0.16435*** (-4.66)	-0.03952 (-1.06)
$nSOI_{t-3}$			0.064431** (1.83)	0.076035* (2.04)
$nSOI_{t-4}$			-0.04358 (-1.23)	-0.00252 (-0.07)
$nSOI_{t-5}$			0.043792 -1.24	0.027165 -0.73
$DWOI_{t-1}$		-1.3406*** (-4.29)	-1.43362*** (-4.58)	-0.77313** (-2.42)

Variable	(1)	(2)	(3)	(4)
$DWOI_{t-2}$			0.208976 -0.67	0.770729** (2.42)
$DWOI_{t-3}$			0.743855** (2.37)	0.832394*** (2.62)
$DWOI_{t-4}$			0.310119 (-0.99)	0.568123* (1.79)
$DWOI_{t-5}$			0.414599 (-1.32)	0.38727 -1.22
$Return_{t-1}$				-0.05985*** (-14.2)
$Return_{t-2}$				-0.03865*** (-9.04)
$Return_{t-3}$				-0.01021** (-2.4)
$Return_{t-4}$				-0.00976** (-2.29)
$Return_{t-5}$				0.003053 (-0.73)
$DwReturn_{t-1}$				0.008819*** (7.34)
$DwReturn_{t-2}$				0.001793 (-1.48)
$DwReturn_{t-3}$				0.001262 (-1.05)
$DwReturn_{t-4}$				-0.00209* (-1.69)
$DwReturn_{t-5}$				0.000038 -0.03
$Turnover_{t-1}$				-0.06656*** (-6.47)
$VolStock_{t-1}$				0.000369*** (-4.16)
$VolDW_{t-1}$				-0.00006 (-1.52)
Hausman test Probability	<.0001	<.0001	<.0001	<.0001
no. of observations	100,428	100,428	100,428	100,428

Variable	(1)	(2)	(3)	(4)
R^2	0.2253	0.2254	0.2257	0.2283

Note: *, **, *** shows a significance level 0.1, 0.05 and 0.01 respectively. The value in the bracket is t-stat.

Table No. 5 The data analysis results of daily underlying stock return prediction using nSOI and DWOI from the following equation:

$$Return_{i,t} = \alpha_{i,t} + \sum_{k=1}^{2} \beta_1^k nSOI_{i,t-k} + \sum_{k=1}^{2} \beta_2^k DWOI_{i,t-k} + \theta X_{i,t-1} + +\alpha_i + \lambda_t + \varepsilon_{i,t}$$

The analysis is divided into 30 minute sessions from 10.30 a.m. to 16.30 p.m., only when the market is actively trading, with the exception of the first three periods due to the reduction of the effect of market opening and data inadequacy in the analysis. $\mathbf{Return}_{i,t}$ is the returns at the period which is calculated by the logarithm of the last price in the previous session minus the logarithm of the last price in the current session. $\mathbf{nSOI}_{i,t-k}$ and $\mathbf{DWOI}_{i,t-k}$ are the nSOI and DWOI calculated at the last moment of certain session. $\mathbf{X}_{i,t-1}$ is the market microstructure controlled variables comprised of returns from two previous sessions, underlying stocks trading volume and derivative warrant trading volume one session prior. α_i is the stock fixed effect. And λ_t is the time fixed effect.

Variable	11.30-12.00	12.00-12.30	14.30-15.00	15.00-15.30	15.30-16.00	16.00-16.30
Intercept	-0.00077 (-1.12)	-0.00024 (-0.35)	-0.00101 (-1.24)	-0.00084 (-1.14)	0.001419* (1.8)	-0.00016 (-0.22)
DWOIt-1	0.227961*** (7.37)	0.236415*** (7.19)	0.262438*** (6.63)	0.264511*** (8.36)	0.240147*** (7.71)	0.247199*** (6.78)
DWOIt-2	0.039429* (1.7)	0.110552*** (3.48)	0.1534*** (3.95)	0.064793* (1.82)	0.103059*** (3.08)	0.10228*** (3.14)
nSOIt-1	0.022762*** (7.89)	0.021437*** (7.09)	0.027395*** (9.51)	0.027851*** (8.62)	0.041799*** (11.83)	0.039159*** (11.13)
nSOIt-2	0.003388 (1.26)	0.005764* (1.92)	0.016989*** (4.66)	0.002131 (0.92)	0.030016*** (8.66)	0.014221*** (3.86)
Returnt-1	-0.21279*** (-53.61)	-0.22891*** (-52.76)	-0.31429*** (-63.87)	-0.1853*** (-50.96)	-0.25477*** (-58.98)	-0.20224*** (-48.53)
Returnt-2	-0.02934*** (-8.11)	-0.05795*** (-13.92)	-0.10262*** (-20.23)	-0.06888*** (-15.32)	-0.03839*** (-10.04)	-0.06006*** (-13.54)
VolStockt-1	-0.000000817 (-0.1)	0.000008012 (0.98)	-0.00000622 (-0.68)	0.000031*** (3.6)	0.000016 (1.84)	0.000029*** (3.41)
VolDW t-1	0.0000001753 (0.02)	0.000013 (1.34)	0.000014 (1.25)	-0.00002* (-1.67)	-0.00000825 (-0.76)	-0.00001 (-1.32)

Variable	11.30-12.00	12.00-12.30	14.30-15.00	15.00-15.30	15.30-16.00	16.00-16.30
Hausman test Probability	0.0350	0.0046	0.0280	<.0001	<.0001	0.0027
no. of observation	72,680	71,143	77,012	75,750	77,193	88,598
R^2	0.1689	0.1442	0.2483	0.2294	0.2183	0.165

Note: *, **, *** shows a significance level 0.1, 0.05 and 0.01 respectively. The value in the bracket is t-stat.

Return Prediction of Intraday Underlying Asset Returns Using nSOI and DWOI

According to Table 5, the DWOI has a positive correlation with the underlying stock price movement at all time frame (significance level 0.01). This outcome demonstrates that the warrant can swiftly transfer information about the underlying asset. However, only the session close to market opening time (10.00 - 10.30 a.m.) can predict the underlying asset's price movement, with the coefficient value at 0.039429 (significance level 0.1). As for the nSOI, the previous session can predict the underlying stock return at a significance level 0.01. Over time, the predictability is reduced to a limited number of sessions. This suggests that derivative warrants have a higher proportion of informative trading than the underlying stock alone. It is speculated that there is a group of uninformed investors actively trading in the underlying stock market.

Discussions and Conclusions

The trading behavior of derivatives warrants and underlying stocks can transmit price information to the market. The discussions and conclusions of this study are organized as follows:

The SOI is correlated to the price movement of the underlying stock on the following day. This relationship is consistent with Chordia, Roll and Subrahmanyam's theory (2002, pp.127-128) which stated that the order imbalance can predict the return in an opposite direction. This is expected to be the result of informed traders' contrarian behavior. We discovered that the DWOI can cause the stock price to adjust higher than the nSOI trading the next day after analyzing the nSOI and the DWOI. As a result, informed traders are more likely to profit from the obtained insights by trading on warrants rather than direct investment. We observed that derivative warrants trading is used to rapidly transmit information from informed traders to the market when we added data from a fixed amount of passing time (lag). Consequently, the underlying stock's price adjusts the following day. On the other hand, the underlying stock trading has a mix of informed and uninformed investors. Thus, the price of underlying stock responds more slowly.

When the control variable was included, it was discovered that the SOI is positively related to price movement but is less significant. It implies that SOI trading behavior is the result of investors who do not exploit their information or seek liquidity, resulting in price pressure. In addition, when analyzing the DWOI to the rate of return, the coefficient value is

negative at the beginning, which is assumed to be influenced by the informed trader. This group of investors has already completed their trading, causing the price to reverse. This analysis is compliance with Avramov, Chordia, and Goyal's theory (2006, p2393) which stated that an uninformed trader will cause the stock to align with the trading behavior due to the herding effect. Whereas, if the transaction was made by the informed investors, the price would reverse due to the contrarian effect. This is because the informed investors will reduce the price volatility. Over time, the effect of DWOI had reversed, demonstrating that the information from informed investors was reduced to only the result of the herding effect from liquidity traders.

The study on intraday order imbalance shows that the DWOI has a statistical correlation with the next session price movement in all sessions (significance level 0.01), without any effect from the reversal later on. It reflects the sensitivity of the informed investor in responding to the price changes in the underlying stock. This result is aligned with the study from Hu (2014, pp 636-637). He discovered that the order imbalance resulted from information effect would be in the same direction.

Baltussen, et al. (2021, p.378) found that intraday leverage behavior of options market makers induces momentum price movements of underlying securities. However, when considering the nSOI, it was found that the SOI transfers information to the underlying stock price at the current time but will decrease in certain sessions as time passes. Due to the large trading volume of the underlying assets, this creates a mix of orders from the informed and uninformed investors, reducing the effect of information over time.

This study can be concluded that the SOI is influenced by the information effect of informational trading. It is result from trading more in derivative warrants than trading directly in underlying stock. Because derivative warrants have a high leverage effect and a low transaction cost, they are accessible to the informed investors who are aware of the underlying stock's actual price. Consequently, when informed investors trade, they transfer information to the market, leading to the price discovery of the underlying stock. When analyzing intraday information transfer, the DWOI outperforms the nSOI in predicting the return of the next session in all time frame. The results demonstrate the sensitivity of the informed traders when the underlying asset price deviates from the obtained data. Therefore, this research accepts the assumptions H1, H2 and H3. All of the above points out that the existence of derivative warrants causes the price of the underlying asset to swiftly move into equilibrium and reduces the information asymmetry among informed and uninformed investors. This is consistent with previous researches (Hu, 2014, p.644; Blanco and Garcia 2021, pp. 15-16; Patel, et al., 2020, p. 23).

Recommendations for Future Research

The results of this research show that derivative warrants are a tool that reduces information asymmetry and enable the true underlying asset value to be discovered. These findings can be used to aid in the research and

development of capital market efficiencies. This may be accomplished by enhancing the presence of derivative warrants through advertising or diversifying publicly traded derivatives to create competition among informed investors. It will shorten the effect of information, thus, reducing the advantage and disadvantage between informed and general traders.

This research focuses on the relationship between the underlying stock and the derivative warrant based solely on a straight line passing through delta value. Further research should be conducted using other types of Options Greek to achieve accessibility and accessibility of non-linear transmission. This study combines the findings of data generated by the trading of all derivative warrants with the same underlying assets. However, different issuers of derivatives warrants exist. To improve market performance, the characteristics of each issuer should be examined.

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