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Intraday Speed of Adjustment and the Realized Variance in the Indonesia Stock Exchange

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We examine the intraday trading and price dynamics for frequently traded stocks at the Indonesian Stock Exchange. Using trade price, time series generated at one, two, three, five, ten, fifteen, thirty and sixty-minute intervals, we estimate the speed of adjustment and the corresponding realized variance of these series. The objective of the estimation is to infer the noise impact to the deviation of observed prices from their fundamental value. The result from the speed of adjustment estimate is consistent with the realized variance estimator. Both conclude that the 50 most frequently traded stocks in the Indonesia Stock Exchange adjust to new information within 30 minutes. At the interval, the coefficient of the speed of price adjustment is insignificantly different from zero implying negligible noise impact to the observed price. Concurrently, the realized variance starts to stabilize at 30-minute interval purporting fading impact of noise to the realized variance estimate. The evidence justifies the use of realized variance at various intervals as a reliable indicator of price discovery rate in the Indonesia Stock Exchange.

Keywords: *speed of adjustment, realized variance, noise*

Introduction

As recognized at least since Hillmer and Yu (1979) Epps (1979), and Patell and Wolfson (1984), evidence that a market is quite efficient (Fama, 1970) over a daily horizon does not preclude inefficiencies at shorter horizons. This is because investors need time to absorb and act on new information.

It is long established that returns are not independent from trade-to-trade or even from minute-to-minute. It must take at least some time for astute investors to figure out what is happening to orders, to ascertain whether there is new pertinent information about values, and to expunge any serial dependence remaining after prices adjust to their new equilibrium levels. The horizon over which this activity takes place is the object of our study. We investigate the time required for prices to adjust to new information in the Indonesian equity market.

Other researchers have investigated questions similar to the one we address,

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but in highly specific contexts. In early work, Patell and Wolfson (1984) show that dividend and earnings announcements ‘‘interrupt’’ the usual pattern of return serial dependence for at least fifteen minutes and that prices do not revert completely to their normal serial correlation pattern for up to ninety minutes around the dividend announcement. Although they make no explicit statement about how this happens, they clearly have in mind the activities of arbitrageurs who offset the impulsive reactions of naïve investors to company announcements.

Garbade and Lieber (1977) formulate a model of independent changes in the equilibrium price coupled with random orders to sell to buy at quoted bid and ask prices. They use data on two stocks for a single month and find that this model does not describe price movements for short time intervals (a few minutes) though it is consistent with price movements over longer horizons. In concluding, Garbade and Lieber recognize that ‘‘…investors who monitor the market continually during the day…’’ might be instrumental in bringing about the observed pattern.

Epps (1979) studies price adjustments for a group of firms in the same industry (automobiles) and finds rapid but not instantaneous adjustments across firms to common news relevant for all industry firms. Correlations among the returns increase with the time interval, which suggests cross-firm variation in the speed of adjustment to new information. Epps’ overall conclusion is that while ‘‘…the predictive value of a price change in one stock endures not much more than one hour,… the average lag in the response of prices (to new information) is more than 10 minutes’’ (p. 298).

More recently, Busse and Green (2002) find that news reports about individual stocks on the financial television network CNBC are incorporated into stock prices within one to two minutes.

Copeland (1976) and Hillmer and Yu (1979) develop related theoretical models. Copeland’s model predicts a positive correlation between trading volume and both absolute price changes and positive skewness in volume; however, it does not include a provision for the activities of arbitrageurs. Hillmer and Yu, on the other hand, note that the incorporation of information into prices ‘‘cannot be completed instantaneously’’ because ‘‘…in practice an investor will not react unless he is convinced that it is economically advantageous.’’ (p.321). Hillmer and Yu develop various alternative statistical models involving price, volume, and volatility, all inspired by the idea that investor/arbitrageurs watch the market closely and react occasionally. Their tests, however, involve only a handful of anecdotal events.

Much later, Chakrabarti and Roll (1999) formulate a model populated by Bayesian traders/arbitrageurs who observe each others trades and attempt to deduce the quality of their information. Simulations of the model show that the market usually converges more rapidly to an equilibrium price that is a better predictor of true value when arbitrageurs react to one another as opposed to trading solely on their own information.

Chordia, et al. (2005) use the order imbalance to analyse the market efficiency for 150 large stocks listed on the New York Stock Exchange for 1996, 1999 and 2002. They found the predictability of returns using imbalances at intervals of up to thirty minutes. The predictability indicates that it takes time for floor traders and other arbitrageurs to compute and react to imbalances. Since imbalances are not public information, outside traders in effect have to apply a rule akin to the Lee and Ready (1991) algorithm to deduce imbalance information, which is a possible reason for the modest predictability of returns out to thirty minutes. Their results

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suggest that wider dissemination of order imbalances by the exchange could bring faster convergence to efficiency.

This study focuses on the intraday activity of the most liquid stocks on the Indonesia Stock Exchange from 2000 to 2007. The intraday activity is an important feature of a stock exchange as it conveys vital information about how the market works. Studies exploring this activity have been focused on markets in the developed world where illiquidity problems for large stocks are fairly negligible. When intraday methodologies developed markets are applied to emerging markets, like Indonesia, the most likely problem is the market illiquidity. This problem, if it is not considered cautiously, could seriously impair any empirical results.

Previous study of the Indonesia Stock Exchange by Henker and Husodo (2006) find that the speed of adjustment for a group of large companies, hence the most liquid ones, is fair at a daily level. Further investigation in the study also finds that for most cases, serial dependence in returns for large stocks is close to zero over a daily horizon. Considering that evidence, our further investigation of the efficiency-creating process must focus on intra-day trading. We would like to measure the interval length required to efficiently measure realized volatility, so it seems sensible to examine frequently traded stocks for which short-term serial dependence can actually be observed. This suggests that very small stocks should be excluded, owing to the difficulty inherent in measuring serial dependence when trading is infrequent.

This study extends the current studies in the area of estimating the speed of adjustment, which mostly focused on the first moment, by analysing the second moment using the realized variance. The original work of Andersen, et al. (2000) uses variance signature plot to assess the impact of market microstructure bias on the realized variance estimates. In this study, we use variance signature plot at different frequency in conjunction with corresponding speed of adjustment to analyse the relation between the noise and the speed of adjustment level.

We find that, on average, the most liquid stocks in the Indonesia Stock Exchange adjust to new information in 30 minutes. Furthermore, we document the empirical relation of market microstructure noise and the speed of adjustment at intraday frequency. Using the realized variance to infer the noise, we find that there is a negative relation between microstructure noise and the speed of adjustment at intraday frequencies.

Literature Review

In this work we use the speed of adjustment estimation and variance signature plots to identify the time required for prices to adjust to new information. The main difference between the speed of adjustment estimation (Theobald and Yallup (2004)) and variance signature plots (Andersen, et al. (2000)) is in the identification of noise. In the former, the impact of noise can be inferred from the moving average component in the ARMA(1,1) structure. While in the latter, the impact of noise manifests itself in the realized variance sampled at high frequency. Both of the methodologies assume independent identically distributed (i.i.d) market microstructure noise in the security process.

The intervalling properties (Theobald and Yallup (2004)) of using ARMA(1,1) structure to estimate the speed of adjustment has a similar hypothesis as the variance signature plot in the way that noise dissipates from price over time. This is where the two methods coincide. Based on that similar hypothesis, we analyse the empirical relation between the speed of adjustment coefficients and their corresponding realized variance. In the absence of noise, the speed of adjustment coefficient will be insignificantly different from one. A speed of adjustment coefficient significantly smaller (larger) than one would indicate an under-reaction (over-reaction) in the adjustment process. Andersen, et al. (2000) and Hansen and Lunde (2006) find that there is a positive bias to the realized variance estimate as the sampling frequency increases. Based upon those empirical findings in the speed of adjustment and realized variance, we conjecture that the speed of adjustment is negatively related with the realized variance. In order to analyse the empirical relation, we compare the level of speed of the speed of adjustment with the corresponding realized variance at a given sampling interval.

The application of variance signature plots in this study has different focus than Andersen, et al. (2000) and Hansen and Lunde (2006). They use variance signature plots to get a general idea of the optimal sampling interval to estimate efficient realized variance with as many observations as possible with minimum market microstructure bias. This study uses the variance signature plots to infer the impact of noise on the deviation of observed prices from their equilibrium.

Speed of Adjustment Estimation

Black (1986) introduces 'noise' as the factor that responsible for the deviation between actual security prices and their intrinsic values. He defines noise as the factor that makes observations imperfect, therefore obfuscating the expected return on a stock or portfolio of stocks.. The 'noise', which is incorporated by Amihud and Mendelson (1987) into a model of partial adjustment with noise, provides the framework for the analysis presented in this study. Their model was an empirical elucidation of the Goldman and Beja (1979) and Garbade and Silber (1979) theoretical model of a price adjustment which assumed that prices were driven by the environment through the market mechanism. The Amihud and Mendelson model distinguished between the intrinsic value of a security at time t, V_t , and its observed price, P_t. The difference between value and price was attributable to noise (Black 1986). Formally, the model is represented as

$$P_t-P_{t-1}= \pi (V_t-P_{t-1})+u_t, \qquad (1)$$

where V_t and P_t are in the natural logarithms and the value of π is in the range of $0 < \pi < 2$, The value of $\{u_t\}$, as commonly applied in the time series literature, has mean zero and finite variance σ^2. The coefficient π, or speed of adjusment coefficient, captures the difference between observed price and value. In addition, $\pi = 0$ is an extreme case where there is no adjustment of price to its intrinsic value, and $0 < \pi < 1$ is called a partial adjustment. Furthermore, a unit adjustment (π=1) means a full adjustment with noisy process, since Eq.(1) reads

$$P_t=V_t+u_t, \qquad (2)$$

i.e. (log) price is given by (log) value plus noise. When the $\pi > 1$, there is an overshooting or overreaction of traders to new information.

Roll (1995) develops an estimation method based on ordinary least squares (OLS) to provide a simpler yet more consistent estimation of the speed of adjustment. He develops the method especially suited to deal with data from the Indonesia Stock Exchange. Specifically, Roll re-expressed the basic setup of Amihud and Mendelson into return form in the following form:

$$R_t= \pi\Delta V_t+(1-\pi)R_{t-1}+\Delta u_t, \qquad (3)$$

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Moreover, Amihud and Mendelson assumed that the unobservable change in log true value V_t-V_{t-1} should be equal to a mean expected rate of return, plus a time-independent, zero mean disturbance, e_t; therefore, (3) can be written as

$$R_t=m+bR_{t-1}+\zeta_t, \quad (4)$$

where b≡1-π and $\zeta \equiv \pi e_t+u_t-u_{t-1}$. However, the estimated slope is biased because the disturbance is still related to the explanatory variable. In addition, Hamilton (1994) argued that the estimation of autoregressive coefficient would produce a downward bias in the OLS setup, therefore the estimate of π will be upward biased.

Further refinement of the estimation of was proposed by Theobald and Yallup (2004) who developed an ARMA (1,1) estimator for Amihud and Mendelson's basic setup. Instead of eliminating the serial dependence in ζ by using every other observation, as Roll did in his model, Theobald and Yallup reformulated Eq.(3) into

$$R_t= \pi\mu+(1-\pi)R_{t-1}+\mu e_t+u_t-u_{t-1}, \quad (5)$$

Within this modelling structure, the autocorrelations induced by under/overreactions are reflected as an ARMA(1,1) process. Effectively, the price adjustment effects manifest themselves within the AR(1) coefficient which will provide an estimate for the speed of adjustment coefficient. A unit adjustment coefficients(i.e. π=1) represents "full" price adjustment; the process will be an MA(1) process. Specifically, "noise" exclusively drives the return process. Additionally, stationarity condition requires that the autoregressive component be |1-π|<1, i.e. 0<π<2, which corresponds to the conditions imposed by Amihud and Mendelson (1987) to ensure that returns were finite when they developed their model.

$$R_{i,t}=c+\rho_i R_{i,t-1}+\varepsilon_{i,t+i},\theta_{t-1}, \quad (6)$$

where $R_{i,t}$ is return of stock i at intraday interval t, ρ and θ were coefficients of the autoregressive and the moving average component respectively. Effectively, the speed of adjustment for each stock was recovered from ρ, where ρ=1-π as in Eq.(5). Furthermore, the cross-sectional average of speed of adjustment was tested for statistical significance from full adjustment (i.e. π = 1) using a t-test. The ARIMA(1,1) estimation as in Eq.(6) is applied to the various intraday interval in this study.

Realized Variance

Assume the availability of M + 1 equispaced price observation over a fixed time span [0,1] (say, a trading day), so that the distance between observations is δ=1/M. The logarithmic observed price $p\sim_{j\delta}$ as the sum of logarithmic efficient price $p^*_{j\delta}$, i.e., the price that would prevail in the absence of market microstructure frictions, and logarithmic market microstructure noise $\eta_{j\delta}$.

$$\tilde{p}_{j\delta} = p^*_{j\delta} + \eta_{j\delta}, \qquad j = 0,2,...,M \quad (7)$$

Both are unobservable. Similarly, in terms of continuously compounded returns,

$$\tilde{r}_{j\delta} = r^*_{j\delta} + \varepsilon_{j\delta}, \qquad j = 1,...,M \quad (8)$$

where

$$\tilde{r}_{j\delta} = \tilde{p}_{j\delta} + \tilde{p}_{(j-1)\delta}, \quad (9)$$

$$r_{j\delta} = p^*_{j\delta} + p^*_{(j-1)\delta}, \quad (10)$$

and

$$\varepsilon= \eta_{j\delta} + \eta_{(j-1)\delta}, \qquad j = 1,2,...,M \quad (11)$$

Eq.(3-9) and Eq.(3-10) have obvious interpretations in terms of efficient return and microstructure noise in the return

process.
Following the previous formulations, the realized variance at frequency δ is defined by,

$$RV^M \equiv \sum_{j=1}^{M} \tilde{r}^2_{j\delta}\ , \qquad (12)$$

and the daily average of realized variance is

$$RV^M = \frac{1}{n} \sum_{n=1}^{n} RV^M\ , \qquad (13)$$

The well-known problem of realized variance estimation is the trade-off between using the highest sampling frequency to make the estimation efficient and minimizing the market microstructure bias as the sampling frequency increases. Andersen, et al. (2000) provide a useful tool to assess the severity of market microstructure bias on the realized variance as the sampling frequency increases by plotting the average realized volatility against the sampling frequency. The plot is well-known as the "volatility signature plot".

Methodology

Sampling Schemes

Intraday returns can be constructed using different types of sampling schemes. The first and the most widely used is calendar time sampling (CTS), where the intervals are equidistant in calendar time. For example, the prices may be sampled every 5 or 15 minutes. CTS requires the construction of artificial prices from the raw (irregularly spaced) price data (transaction prices or quotations). The recorded prices are transformed to equidistant intervals of a particular minute duration using either the previous tick method (Wasserfallen and Zimmermann (1985)) or linear interpolation method (Andersen and Bollerslev (1997)). Hansen and Lunde (2006) show that the previous tick method is a sensible way to sample prices in calendar time. The second sampling alternative is transaction time sampling (TrTS), where prices are recorded every mth transaction. The third sampling scheme is business time sampling (BTS). The last sampling scheme is tick time sampling (TTS), where prices recorded at every price change. An important difference among different sampling schemes is that the observation times under BTS are latent, whereas in CTS, TrTS, and TTS, the observation times are observed.
In this study, CTS is used as sampling schemes to provide the comparability with the speed of adjustment coefficient which is estimated using equidistant interval.

The Data

The data employed in the study, which was obtained from SIRCA, consist of time-stamped trades and quotes, and volumes of trades, bid and ask prices for stocks in the Indonesia Stock Exchange during 2000-2007. WEselect the fifty most frequently traded stocks to be included in the sample. This filtering is an important step to study the intraday properties of transaction data because the illiquidity is a paramount feature in the developing market as in the Indonesia Stock Exchange. Therefore, failure to select the liquid stocks properly would impair our results. Sampled stocks are presented in Table 1. The yearly average trading frequency from 2000 to 2007 for all stocks is 46,213 whereas the average trading frequency for each sampled stock varies from 12,025 to 168,419.

To analyse the dynamic of the speed of adjustment at a trading day, one-, two,- three-, five-, ten-, fifteen-, thirty- and sixty-minute interval of transaction price are generated. We find that multiple transaction prices often have the same time stamp. The various transaction prices are all proxies for the (same) latent efficient price at that particular point in time. Although it is unclear how to best handle such observations, a

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Table 1 Yearly Trading Frequency

The trading frequency is accumulation of daily trading frequency in a year.

No.	Ticker	Trading Frequency								
		2000	2001	2002	2003	2004	2005	2006	2007	Average
1	AALI	16,423	74,988	64,537	39,394	31,258	25,492	25,672	67,312	43,135
2	ANTM	23,597	26,210	27,824	26,681	54,802	56,349	104,192	556,644	109,537
3	ASGR	50,469	68,298	33,716	28,806	16,482	32,032	18,052	64,039	38,987
4	ASII	142,213	187,879	174,520	97,978	72,375	95,850	118,178	114,486	125,435
5	BBCA	9,865	40,892	81,938	73,889	66,767	69,522	89,729	78,543	63,893
6	BBNI	4,429	6,066	13,604	29,653	8,256	6,110	23,811	114,984	25,864
7	BHIT	57,530	26,070	17,165	4,674	5,135	4,645	11,727	95,090	27,755
8	BLTA	15,740	10,198	10,978	7,424	13,224	66,916	140,962	86,470	43,989
9	BMTR	67,571	46,101	13,376	3,217	4,983	3,690	16,740	69,929	28,201
10	BNBR	11,942	15,104	11,554	17,779	88,813	76,694	67,980	196,215	60,760
11	BNGA	6,423	5,921	35,990	15,413	50,156	74,248	74,226	136,624	49,875
12	BNII	17,872	16,669	8,859	25,028	44,711	32,621	46,340	137,158	41,157
13	BUMI	19,997	17,438	7,568	90,790	108,366	109,849	85,394	359,695	99,887
14	CFIN	35,489	11,585	14,042	28,041	46,283	19,485	5,170	16,559	22,082
15	CMNP	27,369	15,662	9,412	13,485	7,016	38,850	55,029	37,520	25,543
16	CTRA	7,060	5,140	2,119	38,595	24,957	19,384	109,689	90,205	37,144
17	CTRS	7,698	10,855	2,712	32,760	19,264	45,679	63,703	30,966	26,705
18	DSFI	42,578	30,084	63,381	10,230	4,681	6,648	2,953	20,123	22,585
19	EPMT	17,339	8,812	9,518	16,110	17,429	15,334	24,078	16,856	15,685
20	FASW	66,732	11,452	3,730	10,323	8,687	9,446	21,488	33,120	20,622
21	GGRM	119,448	114,178	103,163	45,481	34,357	38,445	27,218	19,781	62,759
22	GJTL	37,541	24,340	36,539	52,505	25,821	67,436	39,941	31,766	39,486
23	IGAR	11,464	6,614	8,276	15,365	5,314	11,237	5,892	32,041	12,025
24	INDF	164,343	74,832	64,506	37,563	30,983	90,769	99,336	140,006	87,792
25	INKP	162,103	113,118	59,170	81,347	49,503	130,424	49,660	64,659	88,748
26	INTP	17,946	19,392	13,598	21,931	31,465	42,974	40,616	27,389	26,914
27	ISAT	87,400	98,583	120,701	75,262	92,643	78,695	149,026	76,836	97,393
28	JIHD	30,048	15,423	14,187	14,881	48,141	51,887	18,960	14,082	25,951
29	KIJA	10,929	6,539	7,480	10,704	50,146	44,208	35,578	130,334	36,990
30	KLBF	41,563	37,037	40,938	29,863	46,713	40,987	85,751	58,571	47,678
31	LPLI	136,451	39,887	9,629	5,546	7,078	5,085	5,422	16,824	28,240
32	LSIP	19,682	6,159	10,077	24,367	33,471	40,869	46,220	33,821	26,833
33	LTLS	20,744	9,472	7,792	12,324	12,519	22,267	8,594	25,103	14,852
34	MEDC	46,404	40,406	24,399	10,653	19,964	54,603	95,773	157,800	56,250
35	MLPL	134,065	97,715	45,865	32,273	42,145	43,107	15,160	80,837	61,396
36	MPPA	83,328	51,102	32,347	19,208	9,326	21,969	18,099	28,843	33,028
37	MTDL	81,590	53,857	31,272	11,085	9,814	8,190	3,196	114,613	39,202
38	PNBN	20,411	17,159	28,664	40,350	50,429	48,682	57,353	39,157	37,776
39	RALS	19,565	22,000	37,698	13,925	19,191	19,275	23,590	26,279	22,690
40	SMCB	115,566	9,634	36,529	61,729	54,296	56,175	60,829	68,457	57,902
41	SMGR	22,759	39,561	35,726	13,675	14,752	7,538	14,464	31,809	22,536
42	TINS	32,134	42,844	16,282	26,494	38,361	34,797	50,214	276,490	64,702
43	TKIM	64,243	62,554	15,942	23,464	21,567	44,096	22,395	16,980	33,905
44	TLKM	158,879	218,362	198,571	122,572	119,691	125,479	142,554	261,246	168,419
45	TMPI	67,354	15,270	6,876	4,362	6,004	7,060	20,443	292,153	52,440
46	TRIM	52,565	5,724	4,988	4,485	34,094	10,670	5,132	30,105	18,470
47	TRST	22,208	5,033	9,267	14,900	15,517	8,213	2,887	25,873	12,987
48	TSPC	26,138	16,125	13,902	14,525	8,030	6,722	31,876	37,104	19,303
49	TURI	11,246	9,445	23,779	10,388	15,350	6,250	2,708	53,614	16,598
50	UNTR	38,408	103,202	70,667	50,026	43,840	89,129	62,843	90,140	68,532
	Average	50,097	40,220	34,707	30,230	33,683	41,322	46,937	92,505	46,213

simple and natural estimate of the efficient price (at time t) is the average transaction price (at time t). This is the approach that we take.

The trading hours in the Indonesia Stock Exchange (IDX) on Monday to Thursday are different from those on Friday. In the latter, the IDX trades for only 240 minutes rather than 300 minutes from Monday to Thursday. The trading is executed in two sessions separated by lunch break. Each trading day is initialized by pre-opening session from 09:10:00 to 09:25:00 when buying and selling orders are sent to Jakarta Automated Trading System (JATS), after that, from 09:25:01 to 09:25:59, JATS allocates the orders and forms opening stock prices. For Monday to Thursday, the pre-opening session is followed by first trading session from 09:30 to 12:00 and after lunch break, second trading session initiates from 13:30 to 16:00. Friday trading starts from 09:30 to 11:30 for first session and, after long break for Friday congregational prayer, second trading session resumes from 14:00 to 16:00. As a result, this study manipulates minutes so that the total minutes for each session can be divided evenly into the interval under investigation. For example, the 60-minute interval is problematic since the total trading period for a session is 150 minutes from Monday to Thursday and 120 minutes on Friday. To overcome this problem, this research generates a 60-

Table 2 Yearly Average Speed of adjustment at Various Interval

The speed of adjustment is estimated using ARIMA (1,1) from the 30 most frequently traded stocks in the Indonesia Stock Exchange. T values are presented in parentheses; they are estimated using bootstrap method with replacement replicated on the order of 1000.

Intervals	Year							
	2000	2001	2002	2003	2004	2005	2006	2007
1-min	0.87	0.87	0.89	0.85	0.90	0.86	0.87	0.87
	(-3.67)*	(-2.78)*	(-4.32)*	(-6.87)*	(-1.93)	(-4.00)*	(-5.85)*	(-2.94)*
2-min	0.81	0.81	0.85	0.83	0.89	0.83	0.86	0.77
	(-5.18)*	(-2.92)*	(-5.09)*	(-5.45)*	(-2.66)*	(-7.17)*	(-2.56)*	(-4.64)*
3-min	0.82	0.76	0.83	0.82	0.87	0.79	0.87	0.78
	(-3.58)*	(-2.22)*	(-6.32)*	(-5.97)*	(-1.72)	(-6.22)*	(-1.59)	(-5.33)*
5-min	0.79	0.76	0.88	0.82	0.89	0.79	0.87	0.80
	(-2.71)*	(-4.80)*	(-2.71)*	(-6.89)*	(-1.88)	(-5.36)*	(-4.79)*	(-3.90)*
10-min	0.83	0.82	0.94	0.85	0.92	0.84	0.86	0.92
	(-3.15)*	(-7.62)*	(-2.07)*	(-4.50)*	(-1.50)	(-5.35)*	(-2.23)*	(-1.41)
15-min	0.85	0.92	1.00	0.88	0.92	0.86	0.87	0.91
	(-3.65)*	(-2.12)*	(0.11)	(-3.22)*	(-2.60)*	(-4.96)*	(-5.11)*	(-2.56)*
30-min	0.95	1.00	0.99	0.96	1.00	1.02	1.01	1.00
	(-1.28)	(-0.11)	(-0.12)	(-1.30)	(0.14)	(0.55)	(0.36)	(0.05)
60-min	1.08	0.97	1.05	0.94	0.93	1.13	1.09	1.01
	(0.99)	(-0.46)	(0.68)	(-1.01)	(-1.24)	(2.28)	(1.52)	(0.18)

minute interval for Monday to Thursday by excluding the first 30 minutes of each opening session. Therefore, a total of four observations a day are generated using this method.

Results and Discussion

General Intraday Speed of Adjustment Pattern

We analyse the intraday pattern for each year from 2000 to 2007. From Table 2, overall, the price starts to adjust to new information at 30-minute interval. Occasionally, we find adjustment coefficients that are faster than 30-minute. They are in 2002 and 2004 when fair adjustment starts at 15- and 10- minute interval, respectively. The difference between the speed of adjustment pattern in 2002 and 2004 is that in the latter price under-react to new information at 15-minute interval after full adjustment at previous 10-minute interval. A similar pattern with 2004 has also been found in 2007. It appears that during these intervals, 10- and 15- minute, there is high information uncertainty resulting in mixed reaction.

It is expected that liquid stocks adjust quickly to new information. Here, we estimate the time needed for stock or a group of stocks to adjust to new information at intraday level. The speed of adjustment for the 50 most liquid stocks in the Indonesia

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Table 3. Average Speed of Adjustment from 2000 to 2007

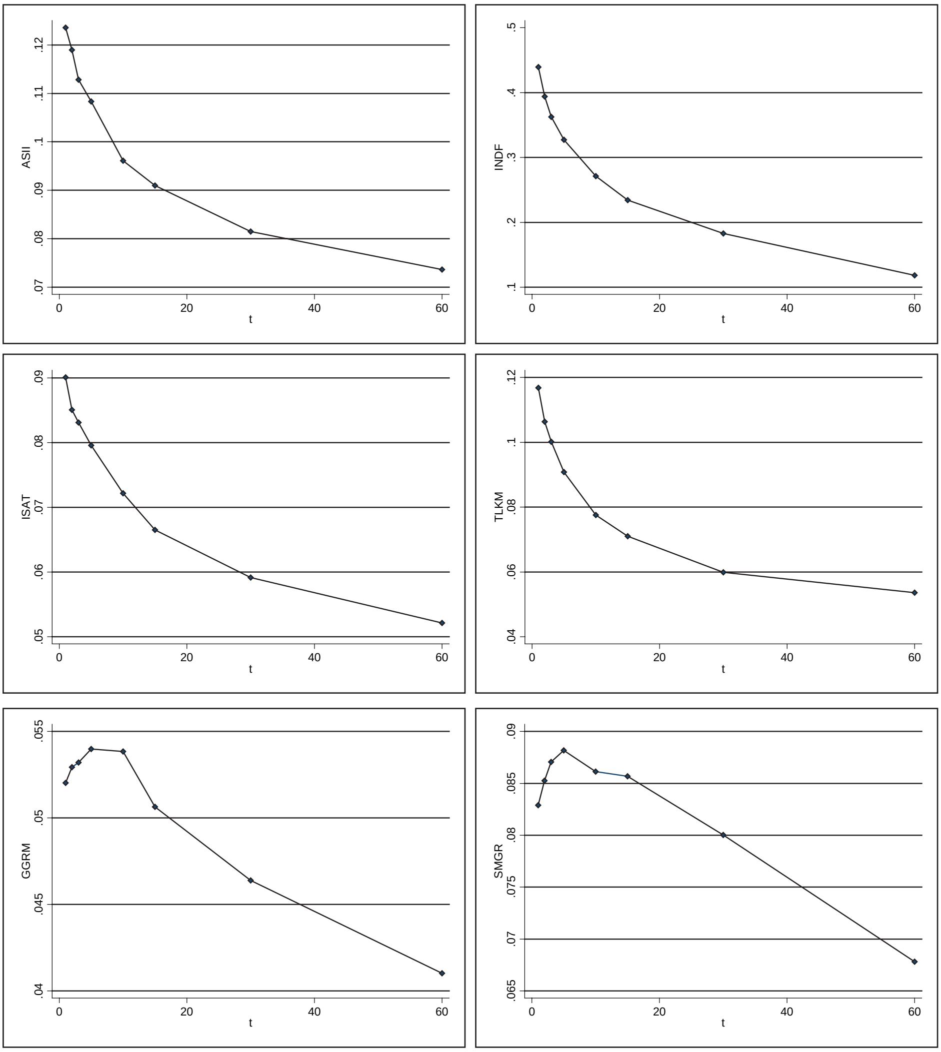
The speed of adjustment is estimated using ARMA(1,1). The data is daily transaction sampled at particular intervals. Speeds of adjustment estimates within the range of 0.95 to 1.05 are printed in bold. Bootstrap method with 1000 replication with replacement is used to estimate t-values for each interval.

Ticker	Interval (minute)							
	1	2	3	5	10	15	30	60
AALI	0.856	0.815	0.768	0.725	0.778	0.924	**0.991**	**1.045**
ANTM	0.842	0.772	0.767	0.795	0.900	0.931	1.127	1.062
ASGR	0.858	0.697	0.741	0.910	0.856	**0.967**	**1.046**	0.823
ASII	0.935	0.689	0.724	0.816	0.893	0.904	1.085	**0.988**
BBCA	0.831	0.763	0.750	0.792	0.823	0.914	1.091	1.071
BBNI	0.894	0.859	0.837	0.819	0.808	0.848	**0.963**	**1.034**
BHIT	0.848	0.819	0.852	0.837	0.898	0.850	0.901	**0.970**
BLTA	0.933	0.731	0.946	0.817	0.901	0.894	**0.956**	**1.013**
BMTR	0.933	0.731	0.946	0.817	0.901	0.894	**0.956**	**1.013**
BNBR	0.929	0.922	0.930	0.934	0.943	**0.963**	**1.034**	0.893
BNGA	0.860	0.845	0.823	0.842	0.870	0.924	0.943	**1.007**
BNII	0.880	0.899	0.905	0.907	0.928	0.945	0.936	**0.965**
BUMI	0.891	0.863	0.873	0.888	0.909	0.946	**1.043**	**0.977**
CFIN	0.848	0.875	0.762	0.774	0.824	0.848	0.937	1.127
CMNP	0.862	0.776	0.742	0.788	0.858	0.858	0.925	0.912
CTRA	0.832	0.746	0.733	0.825	0.860	0.848	**1.040**	0.901
CTRS	0.791	0.808	0.784	0.817	0.894	0.931	**0.996**	1.358
DSFI	0.860	0.823	0.785	0.781	0.851	0.915	0.840	**1.028**
EPMT	0.814	0.815	0.807	0.803	0.886	0.898	**0.969**	1.170
FASW	0.795	0.884	0.891	0.893	0.800	0.850	0.921	0.904
GGRM	0.938	0.765	0.830	0.657	0.849	**0.983**	1.292	0.908
GJTL	0.876	0.861	0.821	0.776	0.839	0.910	**0.990**	1.242
IGAR	0.838	0.851	0.815	0.808	0.846	0.858	0.862	0.827
INDF	**0.951**	0.939	0.936	0.901	0.827	0.832	0.924	1.184
INKP	0.851	0.844	0.811	0.862	0.858	**1.015**	0.906	1.328
INTP	0.891	0.786	0.828	0.811	0.861	0.947	**1.044**	**0.960**
ISAT	1.096	0.737	0.727	0.779	0.932	0.857	1.073	**1.040**
JIHD	0.770	0.790	0.788	0.762	0.845	0.900	**1.027**	1.070
KIJA	0.889	0.886	0.892	0.898	0.922	0.927	**0.991**	1.140
KLBF	0.834	0.804	0.748	0.779	0.832	0.832	**1.020**	1.170
LPLI	0.896	0.904	0.877	0.904	**0.967**	**0.975**	**0.980**	1.104
LSIP	0.805	0.819	0.762	0.772	0.773	0.768	**1.026**	1.223
LTLS	0.828	0.858	0.824	0.824	0.860	**0.964**	**0.971**	0.880
MEDC	0.917	0.881	0.882	0.915	0.903	0.797	**0.955**	0.832
MLPL	0.878	0.863	0.874	0.893	0.871	0.872	**0.992**	1.193
MPPA	0.886	0.845	0.796	0.803	0.851	0.860	**0.991**	1.093
MTDL	0.752	0.815	0.864	0.797	0.888	**0.950**	**0.955**	0.841
PNBN	0.866	0.868	0.849	0.898	0.898	0.930	**1.024**	1.158
RALS	0.866	**1.015**	0.769	0.737	**0.958**	**1.048**	**0.982**	0.867
SMCB	0.849	0.839	0.829	0.833	0.868	0.909	**1.000**	1.068
SMGR	0.938	0.607	0.643	0.823	0.872	0.794	**0.986**	0.930
TINS	0.837	0.795	0.760	0.867	0.919	**1.005**	**0.955**	1.164
TKIM	0.921	0.850	0.718	0.736	0.751	0.847	**1.015**	1.104
TLKM	**0.973**	0.817	0.796	0.810	0.874	**0.972**	**1.048**	0.820
TMPI	0.887	0.855	0.841	0.832	0.870	**0.966**	0.841	0.840
TRIM	0.894	0.888	0.894	0.864	0.887	0.865	0.905	**0.979**
TRST	0.877	0.840	0.881	0.898	0.946	**0.981**	**0.956**	0.735
TSPC	0.790	0.888	0.782	0.795	**0.962**	0.789	1.254	1.228
TURI	0.911	**0.972**	**1.040**	0.817	0.727	0.821	0.863	**0.993**
UNTR	0.885	0.738	0.748	0.786	0.886	0.824	1.082	0.899
Average	0.874	0.827	0.820	0.824	0.870	0.901	0.992	1.022
t-value	(-4.74)	(-7.69)	(-6.79)	(-8.79)	(-9.37)	(-7.87)	(-0.58)	(1.08)

Stock Exchange is estimated for various intervals ranging from 1 to 60 minutes. As presented in the Table 3, on average, the speed of adjustment coefficients from 1-, to 15- minute are between 0.82 and 0.90. All of them are significantly less than one implying under-reaction to new information at these intervals. Giving the market more time to asses and react to new information by increasing the interval to 30-minute resulted in the speed of adjustment coefficient of 0.99. At this

Figure 1. Volatility Signature Plots of Four Selected Stocks

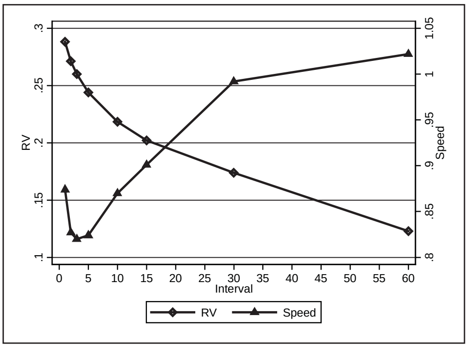
The speed of adjustment is estimated using ARMA(1,1). The data is daily transaction sampled at particular intervals. Speeds of adjustment estimates within the range of 0.95 to 1.05 are printed in bold. Bootstrap method with 1000 replication with replacement is used to estimate t-values for each interval.



interval, the price starts to adjust to new information at a fair level as the coefficient is insignificantly different from unity. The adjustment coefficient at 60-minute is 1.03 and is insignificantly different from one. In sum, the general intraday pattern of the 50 most liquid stocks characterized by strong under-reaction from 1- to 3- minute intervals when the coefficients of adjustment are declining. The coefficient starts to increase gradually from 5-minute interval towards a fair level at 30-minute interval.

Individual Pattern of Intraday Speed of Adjustment

Figure 2. Speed of Adjustment and Realized Variance



Note: The figure presents the plot of speed of adjustment and realized variance at a given interval. Both speed of adjustment and realized variance are estimated from trade prices generated at interval under consideration.

Before going into further analysis, it is important to note that this study arbitrarily uses a range of coefficient from 0.95 to 1.05 to indicate a proximity to fair adjustment at individual stock. At 1-minute interval, there are three stocks that have coefficients in the range of fair adjustment: INDF, ISAT and TLKM. At the next interval, 2-minute, there are two stocks: RALS and TURI. TURI keeps in the fair adjustment rate up to 3-minute interval. At 5-minute interval, we find no stocks have the coefficients of adjustment fall in the range of fair adjustment. There are numbers of stocks fall into the fair adjustment grid at 15-minute interval. They are BNBR, GGRM, INKP, LPLI, LTLS, MTDL, RALS, TINS, TKIM, TLKM, TMPI, and TRST. Almost all stocks have the adjustment coefficients fall into the range of fair level at 30- and 60- minute intervals.

There are two distinctive individual patterns that emerge in this study. The first is a pattern showing a period of information assessment before firmly adjusts to the information. As shown in the Table 3, TLKM starts with a fair adjustment at 1-minute, followed by decreasing speed of adjustment up to 10-minute interval. After that, TLKM move to the fair adjustment area again starting at 15- to 60-minute interval. A similar pattern has also been found in RALS with slightly different starting point of fair adjustment rate at 2-minute. These two stocks demonstrate a periodic adjustment to new information during a trading day. It reflects the information assessment period before firmly adjust at 30-minute interval. The second is a pattern presenting consistent under-reaction for several stocks from 1- to 60- minute interval. They are CMNP, FASW and IGAR. It is unexpected to find such a persistent under-reaction in these stocks since all stocks in the sample are actually the most frequently traded.

The dynamics of speed of adjustment during a trading day for each stock has been revealed. Table 3 shows, although it is not as clear as which had been found in the Lo and MacKinlay (1990), a moderate lead and lag among stocks in the sample is found. The leading stocks, which adjust fairly at one-, two- and three- minute interval, are INDF, TLKM, RALS and TURI. Other stocks, on average, adjust at 30-minute interval.

Volatility Signature Plot and the Speed of Adjustment

Figure 1 presents volatility signature plots for selected stocks classified into two groups. The first group consists of ASII, INDF, ISAT and TLKM which represent upward volatility signature plot as the sampling frequency increases. The second group contains GGRM and SMCB which show downward volatility signature plot as the sampling frequency decreases.

Detailed figures of realized variance for each stock to generate volatility signature plot are presented in Table 4. A very important result from the table is that the volatility signature plots for transaction prices increases as the sampling frequency increases except for GGRM and SMGR. For those stocks, the realized variance decreases

Table 4. Average Daily Realized Variance from 2000 to 2007

Realized variance is estimated by summing intra-period squared returns for a trading day. The figures presented are the daily average realized variance for all year at a given intervals in percentage terms.

Ticker	Interval (minute)							
	1	2	3	5	10	15	30	60
AALI	0.157	0.152	0.147	0.143	0.132	0.125	0.111	0.089
ANTM	0.209	0.196	0.185	0.174	0.154	0.144	0.123	0.096
ASGR	0.239	0.227	0.225	0.214	0.192	0.176	0.150	0.110
ASII	0.124	0.119	0.113	0.108	0.096	0.091	0.082	0.074
BBCA	0.111	0.104	0.102	0.095	0.087	0.078	0.067	0.056
BBNI	0.328	0.312	0.304	0.286	0.264	0.244	0.213	0.142
BHIT	0.183	0.179	0.175	0.170	0.160	0.151	0.137	0.106
BLTA	0.148	0.141	0.135	0.128	0.117	0.109	0.095	0.069
BMTR	0.155	0.151	0.151	0.147	0.141	0.138	0.125	0.102
BNBR	0.721	0.625	0.567	0.488	0.385	0.341	0.265	0.161
BNGA	0.373	0.344	0.324	0.295	0.265	0.240	0.207	0.134
BNII	0.576	0.536	0.509	0.459	0.385	0.329	0.251	0.147
BUMI	0.533	0.471	0.439	0.387	0.323	0.290	0.227	0.144
CFIN	0.286	0.277	0.269	0.260	0.243	0.229	0.202	0.148
CMNP	0.185	0.182	0.176	0.173	0.162	0.157	0.140	0.102
CTRA	0.323	0.310	0.305	0.294	0.267	0.253	0.230	0.177
CTRS	0.262	0.257	0.253	0.243	0.228	0.216	0.192	0.150
DSFI	0.532	0.513	0.495	0.469	0.436	0.409	0.363	0.249
EPMT	0.176	0.174	0.171	0.166	0.157	0.149	0.136	0.103
FASW	0.196	0.194	0.188	0.183	0.174	0.164	0.148	0.125
GGRM	0.052	0.053	0.053	0.054	0.054	0.051	0.046	0.041
GJTL	0.333	0.316	0.303	0.280	0.249	0.236	0.199	0.135
IGAR	0.425	0.404	0.389	0.364	0.331	0.307	0.270	0.177
INDF	0.439	0.394	0.362	0.327	0.271	0.234	0.183	0.118
INKP	0.441	0.408	0.386	0.353	0.300	0.266	0.218	0.157
INTP	0.139	0.136	0.138	0.135	0.125	0.121	0.111	0.086
ISAT	0.090	0.085	0.083	0.080	0.072	0.066	0.059	0.052
JIHD	0.272	0.263	0.257	0.248	0.230	0.216	0.186	0.138
KIJA	0.820	0.757	0.719	0.660	0.559	0.510	0.419	0.263
KLBF	0.223	0.212	0.200	0.189	0.169	0.154	0.135	0.097
LPLI	0.722	0.654	0.602	0.542	0.468	0.415	0.343	0.203
LSIP	0.185	0.181	0.179	0.171	0.161	0.154	0.139	0.106
LTLS	0.162	0.159	0.157	0.154	0.148	0.142	0.131	0.101
MEDC	0.160	0.152	0.145	0.139	0.124	0.119	0.102	0.082
MLPL	0.391	0.363	0.345	0.323	0.281	0.256	0.212	0.143
MPPA	0.323	0.301	0.285	0.268	0.239	0.219	0.186	0.117
MTDL	0.492	0.466	0.452	0.434	0.392	0.360	0.313	0.188
PNBN	0.282	0.266	0.260	0.245	0.219	0.207	0.177	0.127
RALS	0.084	0.084	0.083	0.082	0.079	0.077	0.075	0.063
SMCB	0.317	0.293	0.282	0.262	0.229	0.209	0.177	0.123
SMGR	0.083	0.085	0.087	0.088	0.086	0.086	0.080	0.068
TINS	0.196	0.191	0.185	0.178	0.167	0.156	0.139	0.110
TKIM	0.306	0.296	0.289	0.278	0.248	0.226	0.193	0.145
TLKM	0.117	0.106	0.100	0.091	0.078	0.071	0.060	0.054
TMPI	0.523	0.496	0.478	0.448	0.407	0.386	0.337	0.224
TRIM	0.348	0.333	0.319	0.307	0.286	0.267	0.239	0.153
TRST	0.246	0.239	0.238	0.231	0.214	0.209	0.186	0.134
TSPC	0.080	0.080	0.080	0.078	0.077	0.074	0.069	0.060
TURI	0.135	0.134	0.133	0.131	0.128	0.127	0.119	0.097
UNTR	0.210	0.198	0.192	0.182	0.163	0.149	0.127	0.099
Average	0.288	0.271	0.260	0.244	0.219	0.202	0.174	0.123

as the sampling frequency increases. Andersen, et al. (2000) have also found similar pattern with our study. They explain that the negative bias is most probably caused by inactive trading (illiquidity). With the exception of GGRM and SMGR, the evidence shows that the noise generates positive bias to the transaction prices. This finding is consistent with Hansen and Lunde (2006) who find the positive bias to the transaction prices for 30 equities of the DJIA.

We analyze the variance signature plot in conjunction with the speed of adjustment level to explore the relation between them. The variance signature plot is used to infer the level of noise at a particular sampling interval. From Figure 2, at 1- to 3-minute interval, the speed of adjustment and its corresponding realized variance has

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positive relation. The direction alters to negative relation after 5-minute interval. At 10-minute interval, the speed of adjustment coefficient starts to increase towards a fair adjustment level. Concurrently, the realized variance at the same interval begins to decrease. The speed of adjustment (realized variance) keeps increasing (decreasing) as the sampling interval decreases implying that the lower noise leads to a lower deviation between the observed and the fundamental stock prices. This empirical finding is consistent with Black (1986).

Conclusion

The average speed of price adjustment to new information for frequently traded stocks is 30 minutes in the Indonesia Stock Exchange from 2000 to 2007. There is moderate evidence for a lead and lag structure in the price adjustment to new information.

We find consistently low realized variance when the speed of adjustment is insignificantly different from one for the 50 most frequently traded stocks in the Indonesia Stock Exchange. According to this evidence, we propose volatility signature plot as one of reliable estimate of the price discovery process. Under the assumption of the availability of high-frequency data, the benefit of using the realized variance is clear since this measure is model-free, hence the estimation bias is minimal.

References

Amihud, Y. and Mendelson, H. (1987), Trading Mechanisms and Stock Returns: An Empirical Investigation, *Journal of Finance*, 42, 533-553.

Andersen, T. G. and Bollerslev, T. (1997), Intraday Periodicity and Volatility Persistence in Financial Markets, *Journal of Empirical Finance*, 4, 115-158.

Andersen, T. G., Bollerslev, T., Diebold, F. and Labys, P. (2000), Great Realizations, *Risk Magazine*, 105-108.

Black, F. (1986), Noise, *Journal of Finance*, 41, 529-543.

Busse, J. A. and Green, T. C.(2002), Market Efficiency in Real Time, *Journal of Financial Economics*, 65, 415-437.

Chakrabarti, Rajesh, and Roll, R.(1999), Learning from Others, Reacting and Market Quality, *Journal of Financial Market*, 2, 153-178.

Chordia, Tarun, Roll, R. and Subrahmanyam,A. (2005), Evidence On The Speed of Convergence to Market Efficiency, *Journal of Financial Economics*, 75, 271-292.

Copeland, T. E.(1976), A Model of Asset Trading Under The Assumption Of Sequential Information Arrival, *Journal of Finance*, 31, 1149-1168.

Epps, T. W.(1979), Comovements in Stock Prices in the Very Short Run, *Journal of the American Statistical Association*, 74, 291-298.

Garbade, Kenneth D., and Silber, W. L.(1979), Structural Organization of Secondary Markets: Clearing Frequency, Dealer Activity and Liquidity Risk, *Journal of Finance*, 34, 577-593.

Garbade, Kenneth, and Lieber, Z. (1977), On The Indepence of Transactions On The New York Stock Exchange, *Journal of Banking and Finance*, 1, 151-172.

Goldman, Barry, M. and Beja, A. (1979), Market Prices vs. Equilibrium Prices: Returns' Variance, Serial Correlation, and the Role of the Specialist, *Journal of Finance*, 34, 595-607.

Hamilton, J. D.(1994), *Time Series Analysis*, (Princeton University Press, Princeton, New Jersey).

Hansen,P.R., and Lunde, A.(2006), Realized Variance and Market Microstructure Noise, *Journal of Business and Economic Statistics*, 24, 127-161.

Henker, T. and Husodo, Z. A.(2006), Short Run Behaviour of Stock Returns: Speed of Adjustment and Its Contributing Factors in The Jakarta Stock Exchange, *Working Paper*.

Hillmer, S.C. and P.L. Yu, (1979), The Market Speed of Adjustment to New Information, *Journal of Financial Economics*, 7, 321-345.

Lee, Charles M. C., and Ready, M.J.(1991), Inferring trade direction from intraday data, *Journal of Finance* XLVI, 733-746.

Lo, Andrew, and MacKinlay, A. C.(1990), An Econometrics of Nonsynchronous Trading, *Journal of Econometrics*, 45, 181-211.

Patell, James M., and Wolfson, M.A.(1984), The Intraday Speed of Adjustment of Stock Prices to Earnings and Dividend Announcements, *Journal of Financial Economics*, 13, 223-252.

Roll, R.(1995), An Empirical Survey of Indonesian Equities 1985-1992, *Pacific-Basin Finance Journal* 3, 159-192.

Theobald, M. and Yallup, P.(2004), Determining Security Speed of Adjustment Coefficients, *Journal of Financial Markets*, 7, 75-96.

Wasserfallen, W. and Zimmermann, H. (1985), The Behavior of Intra-Daily Exchange Rates, *Journal of Banking and Finance*, 9, 55-72.

https://scholarhub.ui.ac.id/icmr/vol1/iss1/2
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