# Estimating and Forecasting Intraday Volatility

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## Abstract

The purpose of this study is to investigate stock volatility and forecasting performance of different volatility models over high-frequency intervals. The multiplicative component model that decomposes the conditional variance into a daily component and a periodicity component is studied with different specifications. This model is applied to 30 stocks. For the daily component, both parametric and non-parametric measures are considered. 12 models that capture the long memory feature of volatility are examined. Our results show the HAR-MEM model with overnight jump and the HAR-MEM model have the best forecasting performance among 12 models, and adding an overnight return term improves model's forecasting ability. Periodicity component is captured by the proportion of summation of intraday volatility to summation of daily volatility over some time period. In comparison with the literature, our specification of periodicity component has slightly better forecasting performance in the first 2-hour volatility.

**Keywords**: Intraday volatility, Multiplicative component model, Long memory property

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To my parents.

# Chapter 1

# Introduction

Volatility, which is the variation in asset prices, plays an important role in financial applications. A lot of work has been done on this topic. There are four main reasons why estimating and modeling volatility draw the attention of a large number of researchers and practitioners. Firstly, volatility is the main ingredient for an option pricing model that determines the price of an option. As the level of volatility changes, the option premium will change with it. Secondly, portfolio managers try to maximize expected return with a given set of volatility of different assets in the portfolio optimization process. Moreover, volatility itself has become a new asset class. VIX volatility index started to trade in futures from 2004. Investors could diversify their portfolios by adding volatility financial products. Finally, volatility estimation is essential in many value-at-risk models for risk management, and VaR is a function of volatility. Therefore, accurate measure and good forecast of volatility are critical for these financial applications.

As the computer technology improves, we have access to ultra-high frequency data, which has led to new and prosperous development in estimating, modeling and forecasting daily volatility. In the meantime, as the transaction costs become lower due to electronic trading, more and more people are participating in trading at shorter time horizons less than 1 day. Shorter term volatility is especially critical for those people who would like to trade at a very high frequency and make an investment decision in a short time, whether placing limit orders or market making. An intraday volatility model would be helpful for them to make decisions. However, there is not a lot of development in this area in the past decade. Most researches focus on daily volatility. Therefore, intraday volatility would be our main concern in this paper.

This study attempts to extend the literature of volatility by modeling and forecasting intraday volatility. 30 stocks are included in the sample. In order to select a good model for intraday volatility forecasts, multiplicative component models with different specifications are considered. The conditional variance is decomposed into a daily component and a periodicity component. Each component is estimated separately. For the daily component, we select the top 2 models among 12 models. All 12 models capture long memory property of volatility, and half of them include overnight jump so that we can check whether overnight jump improves forecasting accuracy. To estimate the periodicity component, we use sum of intraday volatility over sum of daily volatility over some period. This periodicity component is used to compare with the literature. Both daily and intraday forecasting results are evaluated by Diebold-Mariano-West test (DMW test). Finally, a combination of these two components is selected as a relatively better intraday model, which might be used in practice.

The remainder of the paper is organized as follows. Chapter 2 reviews the related literature of modeling intraday volatility. Chapter 3 presents the models and specification of variables, estimation method, and the evaluation criteria of forecasting performance of different models. Chapter 4 and Chapter 5 report the results of daily forecasting performance and intraday forecasting performance respectively. Chapter 6 concludes the main results of this project. Other results will be shown in the appendix.

# Chapter 2

# Literature review

Though volatility itself is not directly observable, even ex post, it can be estimated. The simplest way to measure volatility is the squared return, but this estimator is very noisy. Stock price might experience dramatic change, while the return remains small for a particular day. Therefore, there are a lot of studies trying to improve estimation accuracy of volatility. One widely used measure is realized variance (RV), which is the sum of squared asset returns sampled at some time horizons, usually at 5 minutes. Andersen et al. (2001), Andersen et al. (2003) and Barndorff-Nielsen and Shephard (2002) have rigorously developed the theory of RV. As the sampling frequency becomes higher, this measure is easily contaminated by microstructure effects, leading to a biased and inconsistent estimator of integrated variance. Alternative measures that are robust to some microstructure noise have been proposed, including multi-scale estimators of Zhang et al. (2005) and Zhang (2006), the pre-averaging estimator of Jacod et al. (2009), and the realized kernel of Barndorff-Nielsen et al. (2008). All realized measures are described as non-parametric

estimates. Tse and Yang (2012) propose a parametric way to estimate volatility by integrating the instantaneous conditional return variance per unit time derived from an Autoregressive Conditional Duration (ACD) model. Their Monte Carlo results show that the ACD-ICV method has lower RMSE than RV methods over a range of stochastic volatility models when estimating daily volatility.

Conventional GARCH models are not adequate for modeling returns sampled at high frequency intervals, mainly because they fail to control for the intraday patterns of volatility. Andersen and Bollerslev (1997) express conditional variance as the product of a daily component and a diurnal component, and applied the model to deutschemark-dollar exchange rate. Andersen and Bollerslev (1998) add macroeconomic announcement into their model. Engle and Sokalska (2012) apply the multiplicative component GARCH model to stocks, which is the first paper that deals with stock market. They decompose every 10-minute conditional variance into a daily component, a diurnal component and a stochastic intraday volatility component which can be easily estimated. This model is especially suitable for processing a large number of equities. Total volatility in these high frequency models is described by the product of several components, and different specifications are given to each component.

There are several ways to estimate the periodicity component. Andersen and Bollerslev (1998) use flexible Fourier form (FFF) to capture intraday periodicity. This method assumes that intraday pattern remains the same every day. Engle and Sokalska (2012) use averaging of high frequency returns over daily component over a number of trading days, which allows free daily shape.

Modeling daily volatility has been actively studied in the past three decades. Since ARCH model was proposed by Engle (1982) and generalized by Bollerslev (1986), the ARCH-GARCH family of models has been extensively explored and improved (Chou (1988), Glosten et al. (1993), Nelson (1991), Engle and Ng (1993), Zakoian (1994)). As it is well known that financial data such as stock returns exhibits long memory feature, models that capture long memory provide better forecasting performance. ARFIMA model has been widely used. Heterogeneous Autoregressive model of Corsi (2009) that regresses over different time spans of volatility is easily estimated and provides exceptional forecasting performance. Han et al. (2012) propose a modified multiplicative error model that incorporates the heterogeneous components of Corsi's (2009) model, and their finding shows the HAR-MEM model outperforms the HAR model.

During non-trading period, events can occur that have substantial influence on asset price. Gallo (2001) suggests the information contained in the overnight returns (measured as open-to-previous close differences) can be useful in explaining the volatility of the intra-daily returns (measured as close-to-open differences). Using cross listed firms in different exchanges, Chan et al. (2000) show that overnight returns have significant effects on intra-daily returns for the first half hour after the market open.

Engle and Sokalska (2012) decompose the conditional variance into a daily component, a periodicity component, and a stochastic intraday volatility component. They use commercially available volatility forecasts for daily component, average of intraday return proportion as periodicity component, and a GARCH model for the stochastic intraday volatility component. There are 4 important aspects in which this study is different from the Engle-Sokalska model. Firstly, they have 3 components in the model while we only

have 2 components: a daily component and a periodicity component. Our forecast is based on the information up to the beginning of each forecasting day. In Engle-Sokalska model, forecast is based on the information up to the beginning of the forecasting time interval. Hence, we don't have the third stochastic intraday volatility term. Secondly, we forecast daily volatility within the model, whereas they use commercially available volatility forecasts produced for each company. Our daily forecasts results are obtained after comparing 12 daily volatility models. Thirdly, we have a different approach to measure the intraday periodicity component. We will compare the influence of these two different periodicity components in the intraday volatility forecasts. Finally, Engle and Sokalska exclude the overnight returns, whereas our model takes the overnight returns into consideration by adding it to the daily component modeling.

# Chapter 3

# The models

Let $t = 1, 2, 3, ..., T$ denote days in sample. Each day is divided into M intervals. Return for $i$th interval of day $t$ is defined as $r_{t,i} = \log p_{t,i} - \log p_{t,i-1}$ where $t = 1, 2, ..., T$, $i = 1, 2, ..., M$. The process of high frequency return can be described as

$$r_{t,i} = \sqrt{h_t s_i} \varepsilon_{t,i}, \qquad \varepsilon_{t,i} \sim N(0, 1) \tag{3.1}$$

where

$r_{t,i}$ is the high-frequency return in the $i$th interval of day $t$.

$h_t$ is the daily variance component of day $t$.

$s_i$ is the periodicity component of the $i$th interval.

$\varepsilon_{t,i}$ is the error term in the $i$th interval of day $t$.

Our model is based on the Engle-Sokalska model (2012) that decomposes the intraday conditional variance into a daily component, a periodicity component and a stochastic intraday volatility component. The starting point of our forecasting process is at the begin-

ning of each forecasting day. In other words, once the market is open, we can get intraday volatility forecasting result of any time interval of the day. Hence, we don't have the intraday stochastic volatility term in the Engle-Sokalska model. Our model decomposes the conditional variance into the product of a daily component and a periodicity component. Each component is estimated separately. The error term $\varepsilon_{t,i}$ is an $iid$ normal distribution.

## 3.1 Estimation of the daily component

### 3.1.1 Daily models

There are many ways to model daily volatility due to the large number of studies in this area. Most studies of forecasting intraday volatility model daily component with a GARCH model. Engle and Sokalska (2012) use commercially available volatility forecasts produced for each company, which we don't have access to. We use economic models to obtain volatility forecasting results, which is a theoretically rigorous and empirically feasible approach to researchers. In this paper, we focus on models that take long memory property of financial data into consideration. Volatility can have autocorrelations which are significant for many lags. In this multiplicative component intraday volatility forecasting model, accurate daily volatility forecast is critical for intraday volatility forecasting. We compare 12 models and select the top 2 models for intraday study later. The 12 models are divided into 2 groups, one group with the overnight jump and one without. Overnight returns may have explanatory power on volatility which also would improve forecasting accuracy of the model.

The first group is described as follows. We first consider the basic Heterogeneous Autoregressive model (HAR) of Corsi (2009), which is given by

$$RM_t = \alpha_0 + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \epsilon_t \tag{3.2}$$

where

$$RM_{t-1}^{(5)} = \frac{1}{5}\sum_{i=1}^{5} RM_{t-i} \qquad \text{and} \qquad RM_{t-1}^{(22)} = \frac{1}{22}\sum_{i=1}^{22} RM_{t-i} \tag{3.3}$$

$RM_t$ is the realized measure of volatility of day $t$. As shown in equation (3.3), $RM_{t-1}^{(5)}$ is the average of the most recent five daily volatilities, called the medium-term return. $RM_{t-1}^{(22)}$ is the average of the most recent 22 daily volatilities, called the long-term return. There are several advantages of using the HAR model. First, the parameters of this model are easy to estimate, as only OLS method is needed. Second, this model captures long memory property that is very common in financial data. Third, despite its simple form, it produces forecasting performance that is comparable to the ARFIMA, which is more complicated to estimate than the HAR model.[1] Practitioners have more motivation to use the HAR model. [2]

The second and the third models are derived from the HEAVY model (High frEquency bAsed VolatilitY) which is proposed by Shephard and Sheppard (2010). The HEAVY

[1] See Corsi (2009).

[2] We tried to equivalent using different lags to replicate medium-term return and long-term return, but the results are quite close to the HAR model. Hence, we only consider the model in equation (3.2) in this study.

model can be described as follows.

$$\mathrm{Var}(r_t|\mathcal{F}_{t-1}) = \sigma_t^2 = \omega + \alpha RM_{t-1} + \beta\sigma_{t-1}^2, \quad \omega, \alpha \geq 0, \beta \in [0,1) \tag{3.4}$$

$$\mathbb{E}(RM_t|\mathcal{F}_{t-1}) = \mu_t = \omega_R + \alpha_R RM_{t-1} + \beta_R \mu_{t-1}, \quad \omega_R, \alpha_R, \beta_R \geq 0, \quad \alpha_R + \beta_R \in [0,1) \tag{3.5}$$

We consider a modified multiplicative error (MEM) model that incorporates Corsi's (2009) long memory components. It adds another two terms, namely a medium-term return and a long-term return into equation (3.5). Han et al. (2012) call this model the HAR-MEM model.

$$RM_t = \mu_t \eta_t, \qquad \eta_t|\mathcal{F}_{t-1} \sim D(1, \psi) \tag{3.6}$$

$$\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta\mu_{t-1} \tag{3.7}$$

where $\mu_t$ is the conditional expectation of volatility. $RM_{t-1}^{(5)}$ and $RM_{t-1}^{(22)}$ are specified the same way as in (3.3).

The MEM model may be useful in modeling non-negative and persistent processes. This model has more persistence than the HAR model, because $\mu_{t-1}$ also produces persistence. We assume $\omega, \alpha_1, \alpha_2, \alpha_3, \beta \geq 0$ to guarantee the non-negativity of $\mu_t$. As discussed by Engle (2002), a sufficient condition for the covariance stationarity of $RM_t$ is $\alpha_1 + \alpha_2 + \alpha_3 + \beta < 1$. The conditional distribution of the error term $\eta_t$ can be specified to any distribution as long as the mean is equal to 1 and pdf is defined over $[0, +\infty)$. In this paper, we assume $\eta_t$ follows an exponential distribution.

In the third model, we incorporate the medium-term return and the long-term return into equation (3.4). We call it the HAR-MEM-$r$ model, which is defined as

$$r_t = \sigma_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim N(0,1) \tag{3.8}$$

$$\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \sigma_{t-1}^2 \tag{3.9}$$

Where $\sigma_t^2$ is the conditional variance. $RM_{t-1}^{(5)}$ and $RM_{t-1}^{(22)}$ are specified the same way as in equation (3.3).

HAR-MEM-$r$ model is directly derived from the HEAVY model that uses realized measure to forecast a latent volatility, while HAR-MEM just takes the form of the HEAVY model. HAR-MEM forecasts realized measure. There are several differences between Model 2 and Model 3. The left-hand side of equation (3.5) is a realized measure, while the left-hand side of equation (3.9) is return. The return is defined as the difference of the logarithmic closing price and the opening price of day $t$. The other difference is in the specification of the error term. HAR-MEM model requires the error term to have mean 1, while the HAR-MEM-$r$ model needs an error term with mean 0 and variance 1. In model 3, the error term is specified to have a standard normal distribution.

Model 4 to Model 6 adopt a different way to capture the long memory property, using linearly declining weights for different lags instead of uniform weight for lags. This method gives more weight to lags closer to day $t$, while giving less weight to the days further away from day $t$. The sum of the weights equals 1. The weights $w_i$ are defined by

$$w_i = \frac{(q+1) - i}{0.5 * q(q+1)} \tag{3.10}$$

where $w_i$ is the weight for $i$th day's lag, and $q$ is the maximum lag.

In order to make comparison with previous models, we choose 22 as maximum lag for Model 4 to Model 6. The fourth model is similar to the HAR model except for the two long memory terms, which equals one. We call it the W-HAR model, which is given by

$$RM_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \epsilon_t \tag{3.11}$$

where

$$RM_{t-1}^{(w)} = \sum_{i=1}^{22} (w_i * RM_{t-i}) \tag{3.12}$$

$RM_{t-1}^{(w)}$ is the volatility based on linearly declining weights of 22 lags.

The same change is also made to the HAR-MEM model and the HAR-MEM-$r$ model. Therefore, Model 5 and Model 6 are expressed as follows.

The fifth model is the W-HAR-MEM model

$$RM_t = \mu_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim D(1, \psi) \tag{3.13}$$

$$\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \mu_{t-1} \tag{3.14}$$

The sixth model is the W-HAR-MEM-$r$ model

$$r_t = \sigma_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim N(0, 1) \tag{3.15}$$

$$\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \sigma_{t-1}^2 \tag{3.16}$$

For Model 7 to Model 12, we add an overnight jump term to Model 1 to Model 6 correspondingly. During non-trading time, though no trade happens, significant event or news might be released that have impact on the stock price. Thus, incorporating overnight returns into the models may improve the daily volatility forecasting performance. A comparison between models with overnight jump and without overnight jump will be made. The overnight jump is defined as the squared difference between the logarithmic opening price of day $t$ and the logarithmic closing price of day $t-1$.

$$OJ_{t-1} = (\log p_{o,t} - \log p_{c,t-1})^2 \tag{3.17}$$

For convenience, we write Model 7 to Model 12 as follows. Model 7 is the HAR model with overnight jump, namely HAR-OJ,

$$RM_t = \alpha_0 + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \gamma OJ_{t-1} + \epsilon_t \tag{3.18}$$

where $OJ_{t-1}$ is defined in equation (3.17).

Model 8 is the HAR-MEM-OJ model, which is defined as

$$RM_t = \mu_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim D(1, \psi) \tag{3.19}$$

$$\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \mu_{t-1} + \gamma OJ_{t-1} \tag{3.20}$$

Model 9 is the HAR-MEM-$r$-OJ model, which is defined as

$$r_t = \sigma_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim N(0,1) \tag{3.21}$$

$$\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \sigma_{t-1}^2 + \gamma OJ_{t-1} \tag{3.22}$$

The HAR-MEM-OJ model forecasts the expectation of realized measure of volatility. We adopt unit exponential distribution for the error term $\eta_t$ in the HAR-MEM-OJ model, because it has non-negative support and mean 1. This is a modified MEM model. QMLE based on exponential distribution of the error term yields consistent estimators regardless of whether the density function is truly specified (Drost and Werker (2004)). In the HAR-MEM-$r$-OJ model, it forecasts the standard deviation of asset prices using realized measure of volatility. We assume a standard normal distribution for the error term in the HAR-MEM-$r$-OJ model. The resulting estimators by QMLE are still consistent even the real distribution of error term is not normal.

Model 10 is the W-HAR-OJ model, which is defined as

$$RM_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \gamma OJ_{t-1} + \epsilon_t \tag{3.23}$$

Model 11 is the W-HAR-MEM-OJ model, which is defined as

$$RM_t = \mu_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim D(1, \psi) \tag{3.24}$$

$$\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \mu_{t-1} + \gamma OJ_{t-1} \tag{3.25}$$

Model 12 is the W-HAR-MEM-$r$-OJ model, which is defined as

$$r_t = \sigma_t \eta_t, \qquad \eta_t | \mathcal{F}_{t-1} \sim N(0,1) \tag{3.26}$$

$$\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \sigma_{t-1}^2 + \gamma OJ_{t-1} \tag{3.27}$$

### 3.1.2 Estimation method

The above 12 models can be grouped by different estimation methods. Table 3.1 shows the different groups. The first group can be estimated by just simple OLS. The second and the third group are estimated by the quasi-maximum likelihood estimate (QMLE), with which produces consistent and asymptotically normal estimators as discussed by Engle (2002). The log-likelihood function for the second group of models is

$$\sum_{t=23}^{T} \ell_t(\theta) = -\sum_{t=23}^{T} (\log \mu_t + RM_t/\mu_t) \tag{3.28}$$

where $\mu_t$ follows four different processes in this group, and $RM_t$ is the realized volatility measure.

The log-likelihood function for the third group is

$$\sum_{t=23}^{T} \ell_t(\theta) = -\frac{1}{2} \sum_{t=23}^{T} (\log \sigma_t^2 + r_t^2/\sigma_t^2) \tag{3.29}$$

where $\sigma_t^2$ follows the processes in group 3, and $r_t^2$ is the squared return.

Table 3.1: Summary of Models

| Estimation | Model | Specification |
|---|---|---|
| OLS | HAR | $RM_t = \alpha_0 + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \epsilon_t$ |
| | HAR-OJ | $RM_t = \alpha_0 + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \gamma OJ_{t-1} + \epsilon_t$ |
| | W-HAR | $RM_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \epsilon_t$ |
| | W-HAR-OJ | $RM_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \gamma OJ_{t-1} + \epsilon_t$ |
| QMLE for $RM_t$ | | $RM_t = \mu_t \eta_t \qquad \eta_t \vert \mathcal{F}_{t-1} \sim D(1, \psi)$ |
| | HAR-MEM | $\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \mu_{t-1}$ |
| | HAR-MEM-OJ | $\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \mu_{t-1} + \gamma OJ_{t-1}$ |
| | W-HAR-MEM | $\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \mu_{t-1}$ |
| | W-HAR-MEM-OJ | $\mu_t = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \mu_{t-1} + \gamma OJ_{t-1}$ |
| QMLE for $r_t$ | | $r_t = \sigma_t \eta_t \qquad \eta_t \vert \mathcal{F}_{t-1} \sim N(0, 1)$ |
| | HAR-MEM-$r$ | $\sigma_t^2 = \sigma + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \sigma_{t-1}^2$ |
| | HAR-MEM-$r$-OJ | $\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(5)} + \alpha_3 RM_{t-1}^{(22)} + \beta \sigma_{t-1}^2 + \gamma OJ_{t-1}$ |
| | W-HAR-MEM-$r$ | $\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \sigma_{t-1}^2$ |
| | W-HAR-MEM-$r$-OJ | $\sigma_t^2 = \omega + \alpha_1 RM_{t-1} + \alpha_2 RM_{t-1}^{(w)} + \beta \sigma_{t-1}^2 + \gamma OJ_{t-1}$ |

## 3.2 Estimation of the periodicity component

$s_i$ is the intraday periodicity component, where $i$ is the $i$th intraday interval. In this paper, we denote $s_i$ as following process

$$s_i = \frac{\sum_{t=T-251}^{T} ICV_{t,i}}{\sum_{t=T-251}^{T} h_t} \tag{3.30}$$

$s_i$ is the sum of intraday volatility over sum of daily volatility. The period we used to calculate $s_i$ is most recent 252 days to day $T$. $ICV_{t,i}$ is the intraday volatility which is defined as the volatility of time horizons shorter than 1 day. We estimate intraday volatility by the ACD-ICV method that is proposed by Tse and Yang (2012). The ACD-ICV method integrates conditional variance (ICV) per unit time derived from an Autoregressive Con-

ditional Duration (ACD) model. $h_t$ is the daily volatility. We also use the ACD-ICV method to estimate daily volatility. ACD-ICV method can provide good estimate for high-frequency volatility.

In order to compare with the literature, here we introduce Engle and Sokalska's (2012) approach to estimate the periodicity component.

$$s_i^E = \frac{1}{T}\sum_{t=1}^{T}\frac{r_{t,i}^2}{h_t} \tag{3.31}$$

We call this periodicity component $s_i^E$. $r_{t,i}^2$ is the squared return of $i$th interval on day $t$. $h_t$ the is the daily volatility that is estimated by the realized kernel (RK) method. $s_i^E$ is the average of high-frequency return over daily volatility.

## 3.3 Forecasting procedure and evaluation

In order to compare the forecasting accuracy of different models, we use the Diebold-Mariano-West (DMW) test (See Diebold and Mariano (1995), West (1996)). Both daily forecast and intraday forecast results are evaluated by this method.

### 3.3.1 One-day ahead daily volatility forecasts

In this part, we only focus on one-day ahead daily volatility forecast, because our main goal is to forecast intraday volatility. We adopt the rolling window procedure with moving windows of eight year (2016 trading days) for one-day ahead forecast. This method estimates model on the sample running from $t-s, t-s+1, ..., t$, and produces forecasts of

the variable at date $t+h$. In our case, $s$ is 2015, and $h$ is 1. Because volatility is not directly observable, even ex-post, we need proxy of unobserved true volatility. We consider $r_t^2$, $RV$ and ACD-ICV as proxy. Among these three proxies, only $r_t^2$ is unbiased, so this would be the main reference.

Before taking the test, we need to decide which loss function to use. Patton (2011) shows that MSE and QLIKE are robust to noisy volatility proxies. Patton and Sheppard (2009) show that the QLIKE loss function is more effective than other loss functions in their simulation study. This paper considers both QLIKE and MSE. The QLIKE loss function is

$$L(\widehat{RM}_t, RM_t) = \frac{RM_t}{\widehat{RM}_t} - \log \frac{RM_t}{\widehat{RM}_t} - 1 \tag{3.32}$$

The MSE loss function is

$$L(\widehat{RM}_t, RM_t) = (\widehat{RM}_t - RM_t)^2 \tag{3.33}$$

where $RM_t$ is the true volatility on day $t$ and $\widehat{RM}_t$ is the forecasting result of volatility of day $t$ based on the information up to day $t-1$ in both loss functions.

We select the HAR-MEM model as the benchmark model, and the other 11 models are compared against the benchmark model pairwise using both QLIKE and MSE. The difference between the loss function of the two models being compared is denoted by $d_t$, where

$$d_t = L(\widehat{RM}_t, RM_t) - L(\widehat{RM}_t^{benchmark}, RM_t), \tag{3.34}$$

here $\widehat{RM}_t$ is the volatility forecasts from the model being compared. $\widehat{RM}_t^{benchmark}$ is volatility forecasts of the benchmark model. The DMW statistic is

$$DMW_{T_F} = \frac{\sqrt{T_F\,\overline{d}_T}}{\sqrt{\widehat{avar}(\sqrt{T_F\,\overline{d}_T})}}, \tag{3.35}$$

where $\overline{d}_T$ is the sample mean of $d_t$ and $T_F$ is the number of forecasting observations. The asymptotic variance of the average is computed using a Newey-West variance estimator with the number of lags set to 10. If the DMW statistic between one model and the benchmark model is negatively significant, this model provides better forecasts than the benchmark model. If the DMW statistic is positively significant, then benchmark model is better.

### 3.3.2 Intraday volatility forecasting evaluation

With the one-day ahead forecasting $\hat{h}_{t+1}$ and the periodicity estimate $\hat{s}_i$, we can compute intraday volatility forecasts which multiplies $\hat{h}_{t+1}$ by $\hat{s}_i$ for $i$th interval. The results are also evaluated by the DMW test. The QLIKE loss function becomes

$$L(\widehat{RM}_{t,i}, RM_{t,i}) = \frac{RM_{t,i}}{\widehat{RM}_{t,i}} - \log\frac{RM_{t,i}}{\widehat{RM}_{t,i}} - 1, \tag{3.36}$$

The MSE loss function becomes

$$L(\widehat{RM}_{t,i}, RM_{t,i}) = (\widehat{RM}_{t,i}, -RM_{t,i})^2, \tag{3.37}$$

where $RM_{t,i}$ is the true volatility of day $t$ at $i$th time interval and $\widehat{RM}_{t,i}$ is the forecasting result of volatility of day $t$ at $i$th time interval.

Now, the difference of loss function between two models $d_{t,i}$ becomes

$$d_t = L(\widehat{RM}_{t,i}, RM_{t,i}) - L(\widehat{RM}_{t,i}^{benchmark}, RM_{t,i}) \tag{3.38}$$

here $\widehat{RM}_{t,i}$ is the volatility forecast of the model being compared at $i$th interval on day t. $\widehat{RM}_{t,i}^{benchmark}$ is the forecast of benchmark model at $i$th interval.

The DMW statistic is

$$DMW_{T,i_F} = \frac{\sqrt{T_F\ \overline{d}_{T,i}}}{\sqrt{\widehat{avar}(\sqrt{T_F\ \overline{d}_{T,i}})}} \tag{3.39}$$

Basically the procedure is similar to the forecasting evaluation for the daily component, except intraday volatility has short time horizons.

# Chapter 4

# Empirical analysis

## 4.1 Data

We select 30 large market-cap and actively traded stocks from S&P 500 index components for this study. We use high-frequency tick-by-tick trades. All stocks in the sample are traded in NYSE (New York Stock Exchange). In order to take long memory property into consideration, we need a longer sample. The time span of the data is from January 04, 1993 to December 31, 2007. Before fitting models to the data, the data need to be cleaned. We exclude data from trading days that had the first transaction after 11:00 or last transaction before 14:00, because these unusual days might contaminate the results. With such a long time period, it's hard to avoid stock splits. Unusual days with stock split are removed from the sample. Other cleaning procedures are the same adopted as those by Barndorff-Nielsen et al. (2009). Table 4.1 shows short description of stocks.

Table 4.1: Data description of each stock

| Ticker | Company name | Days | Avg trans per day | Mean daily return (%) | Std dev of return (%) | Kurtosis |
|---|---|---|---|---|---|---|
| IBM | International Business Machines Corp. | 3736 | 3385 | 0.0088 | 1.65 | 6.77 |
| GE | General Electric Co. | 3733 | 4015 | 0.0047 | 1.46 | 7.14 |
| MO | Altria Group Inc. | 3731 | 2829 | -0.0100 | 1.60 | 10.51 |
| MRK | Merck & Co. | 3705 | 2841 | 0.0499 | 1.52 | 6.92 |
| KO | Coca-Cola Co. | 3726 | 2401 | 0.0638 | 1.32 | 7.41 |
| PFE | Pfizer Inc. | 3733 | 3532 | -0.0175 | 1.62 | 5.68 |
| JNJ | Johnson & Johnson | 3733 | 2739 | 0.0250 | 1.30 | 5.27 |
| AIG | American International Group Inc. | 3734 | 2751 | -0.0103 | 1.52 | 6.90 |
| PG | Procter & Gamble Co. | 3738 | 2711 | 0.1067 | 1.33 | 8.15 |
| WMT | Wal-Mart Stores Inc. | 3680 | 3089 | -0.0585 | 1.65 | 6.76 |
| JPM | JPMorgan Chase & Co. | 3720 | 3152 | 0.0177 | 1.87 | 17.41 |
| PEP | PepsiCo Inc | 3721 | 2269 | 0.1372 | 1.39 | 10.40 |
| DD | E.I. DuPont de Nemours & Co. | 3736 | 2149 | 0.0198 | 1.54 | 6.63 |
| DIS | Walt Disney Co. | 3738 | 2396 | -0.0122 | 1.64 | 5.93 |
| HD | Home Depot Inc. | 3731 | 2875 | -0.0421 | 1.77 | 5.86 |
| BA | Boeing Co. | 3729 | 2303 | 0.0240 | 1.61 | 6.30 |
| MMM | 3M Co. | 3731 | 1978 | -0.0101 | 1.30 | 6.38 |
| AXP | American Express Co. | 3722 | 2364 | 0.0084 | 1.74 | 6.15 |
| T | AT&T Inc. | 3712 | 2790 | -0.0120 | 1.61 | 5.66 |
| MCD | McDonald's Corp. | 3706 | 2113 | 0.0641 | 1.49 | 7.41 |
| SLB | Schlumberger Ltd. | 3738 | 3139 | -0.0280 | 1.91 | 5.09 |
| TXN | Texas Instruments Inc. | 3733 | 3124 | -0.0520 | 2.60 | 5.13 |
| DOW | Dow Chemical Co. | 3735 | 1839 | 0.0279 | 1.62 | 9.93 |
| ABT | Abbott Laboratories | 3728 | 2031 | 0.0770 | 1.54 | 5.12 |
| CL | Colgate-Palmolive Co. | 3736 | 1387 | 0.0710 | 1.39 | 11.14 |
| BAC | Bank of America Corp. | 3734 | 3038 | 0.0226 | 1.62 | 6.54 |
| UTX | United Technologies Corp. | 3728 | 1920 | -0.0027 | 1.51 | 8.62 |
| EMR | Emerson Electric Co. | 3732 | 1474 | 0.0250 | 1.41 | 4.88 |
| MDT | Medtronic Inc. | 3732 | 2043 | 0.0195 | 1.65 | 5.27 |
| UNH | UnitedHealth Group Inc. | 3721 | 2007 | 0.0213 | 1.96 | 8.78 |

Note: Avg trans per day is the average number of transactions each day. Return is the difference of logarithmic prices. Mean daily return (%) is the mean of return in percentage. Std dev of return (%) is the standard deviation of return in percentage. Kurtosis is the kurtosis of return.

Both realized kernel (RK) and ACD-ICV method are used to estimate daily volatility. Among all estimators, RK has achieved success theoretically and empirically. ACD-ICV is a new method, but its simulation results are better than RK. In this paper, a comparison between RK and ACD-ICV is conducted empirically. The details of the specification of each estimator are given in the appendix A.

## 4.2 Daily volatility forecasting comparison

This part illustrates the comparison results of the daily volatility forecasts. Table 4.2 shows the DMW test results by counting the numbers of stocks that have negatively significant DMW test statistics and the numbers of stocks that have positively significant statistics. The details of the test statistics are presented in the Appendix B. The benchmark model is the HAR-MEM model. Negative significance represents the benchmark model is less favorable, while positive significance shows the benchmark model beats the comparison model. From the table we can get several results. Firstly, the HAR model underperforms the benchmark model with RK as the input volatility data and QLIKE loss function as the input of the DMW test. This result is consistent with Han et al.'s (2012) results. If we use ACD-ICV as the input data, there is no significant evidence to show the benchmark model performs better, but most of the DMW statistics are still positive. Secondly, there are 15 stocks of HAR-MEM-OJ that beat the benchmark model when using RK as the input data and QLIKE as the loss function. In other cases, HAR-MEM-OJ model also provides largest number of stocks with better forecasting performance compared to the benchmark model than other models. This means HAR-MEM-OJ is better than the benchmark model.

Moreover, in most cases, models that with linearly declining weights do not outperform the benchmark model, the HAR-MEM model.

Table 4.2: Comparison of daily volatility forecasts with $r_t^2$ as Proxy

| Model | Negatively significant | | | | Positively significant | | | |
|---|---|---|---|---|---|---|---|---|
| | RK | | ICV | | RK | | ICV | |
| | QLIKE | MSE | QLIKE | MSE | QLIKE | MSE | QLIKE | MSE |
| HAR | 0 | 0 | 5 | 0 | 26 | 2 | 2 | 2 |
| HAR-OJ | 1 | 0 | 7 | 1 | 16 | 1 | 1 | 1 |
| W-HAR | 0 | 0 | 1 | 0 | 28 | 5 | 6 | 5 |
| W-HAR-OJ | 0 | 0 | 2 | 0 | 21 | 2 | 3 | 4 |
| **HAR-MEM-OJ** | **15** | **7** | **8** | **3** | **2** | **0** | **0** | **0** |
| W-HAR-MEM | 0 | 0 | 0 | 0 | 1 | 1 | 5 | 2 |
| W-HAR-MEM-OJ | 6 | 3 | 5 | 1 | 1 | 0 | 0 | 2 |
| HAR-MEM-$r$ | 7 | 3 | 0 | 0 | 3 | 5 | 13 | 3 |
| **HAR-MEM-$r$-OJ** | **11** | **1** | **0** | **0** | **1** | **1** | **6** | **0** |
| W-HAR-MEM-$r$ | 7 | 4 | 0 | 0 | 5 | 5 | 13 | 3 |
| W-HAR-MEM-$r$-OJ | 8 | 0 | 0 | 0 | 2 | 2 | 7 | 0 |

Note: This table counts the number of stocks that have either positively or negatively significant DMW statistics. RK is the realized kernel and ICV is the volatility obtained using ACD-ICV method. QLIKE and MSE are the loss function being used in the test. $r_t^2$ is the proxy of true volatility, which is defined as squared difference between the logarithmic opening price and the logarithmic closing price.

Table 4.3 presents a comparison of RK and ACD-ICV estimators. HAR-MEM, HAR-MEM-OJ, HAR-MEM-$r$ and HAR-MEM-$r$-OJ models are estimated using both the RK and ACD-ICV. The reason for choosing these models is because these models have relatively better forecasting performance in the Table 4.2. The benchmark model is the HAR-MEM model with RK. We find that using RK to estimate models gives more stocks that outperform the benchmark model than using ICV method. In addition, The HAR-MEM-OJ model is superior to other models with both ICV and RK as the input volatility data. The HAR-MEM-$r$ model underperforms the benchmark model with ICV as the input volatility data. We will drop HAR-MEM-$r$ and HAR-MEM-$r$-OJ in later study.

Table 4.3: Comparison of RK and ACD-ICV

| Model | Negatively significant | | Positively significant | |
|---|---|---|---|---|
| | QLIKE | MSE | QLIKE | MSE |
| HAR-MEM-OJ(RK) | 15 | 7 | 2 | 0 |
| HAR-MEM-$r$-OJ (RK) | 7 | 3 | 3 | 5 |
| HAR-MEM-$r$(RK) | 11 | 1 | 1 | 1 |
| HAR-MEM(ICV) | 4 | 0 | 3 | 0 |
| HAR-MEM-OJ(ICV) | 7 | 0 | 2 | 0 |
| HAR-MEM-$r$(ICV) | 1 | 0 | 19 | 2 |
| HAR-MEM-$r$-OJ(ICV) | 2 | 0 | 8 | 1 |

Note: This table compares RK to ACD-ICV. The benchmark model is HAR-MEM with RK as the input volatility data. $r_t^2$ is the volatility proxy.

Besides, according to Table 4.4, comparison between the groups that with and without overnight jump shows that models with overnight jump outperform the models without overnight jump, because most of the DMW statistics are negatively significant using Q-LIKE. Overnight jumps do improve the forecasting performance of the daily component in most cases.

Table 4.4: Comparison of models with and without overnight jumps

| Model | Negatively significant | | | | Positively significant | | | |
|---|---|---|---|---|---|---|---|---|
| | RK | | ICV | | RK | | ICV | |
| | QLIKE | MSE | QLIKE | MSE | QLIKE | MSE | QLIKE | MSE |
| HAR-OJ | 16 | 2 | 9 | 3 | 0 | 0 | 0 | 0 |
| HAR-MEM-OJ | 15 | 7 | 8 | 3 | 2 | 0 | 0 | 0 |
| HAR-MEM-$r$-OJ | 9 | 1 | 18 | 0 | 0 | 1 | 0 | 0 |
| W-HAR-OJ | 18 | 3 | 10 | 3 | 0 | 0 | 0 | 0 |
| W-HAR-MEM-OJ | 8 | 2 | 9 | 2 | 0 | 0 | 0 | 0 |
| W-HAR-MEM-$r$-OJ | 5 | 0 | 16 | 0 | 0 | 2 | 0 | 0 |

Note: This table compares models with overnight jump to models without overnight jump. This table counts the number of stocks that have significant DMW statistics. The benchmark model of each model in the table is the one that keeps other specification same, but without overnight jump term. $r_t^2$ is the volatility proxy.

In summary, the HAR-MEM model and the HAR-MEM-OJ model are selected for the intraday volatility forecasts. These models produce better forecasting performance in most cases we consider above.

## 4.3 Intraday volatility forecasting comparison

After selecting daily volatility models, we proceed to forecast intraday volatility. We only consider intraday volatility forecasts in two-hour time horizon. Each day is divided into 3 intervals. We do not include the first 30 minutes of the day in the sample because volatility in these 30-minute intervals are usually very noisy. The time intervals we consider are 10:00 to 12:00, 12:00 to 14:00 and 14:00 to 16:00. We test the results every 252 days using the DMW test, because the test result might be contaminated by structural change, if we use the whole period.

Our results of intraday volatility forecasts with the HAR-MEM-OJ model as the daily volatility forecasting model and with two different ways estimating the periodicity component are shown in the Table 4.5 and Table 4.6. Our benchmark model is the HAR-MEM-OJ model using ICV method as the daily forecasting model and $s_i^E$ as the periodicity component. Here we write the benchmark model HAR-MEM-OJ(ICV)($s_i^E$) for convenience. In the first two-hour volatility forecast, if we take the whole forecasting observations into consideration, the test results show that the HAR-MEM-OJ(ICV)($s_i$) model has the best performance using the MSE loss function, and the HAR-MEM-OJ(RK)($s_i^E$) model and the HAR-MEM-OJ(ICV)($s_i$) model are both superior to the benchmark model if we use the QLIKE loss function for the test. However, If we take the DMW test every 252 days, the HAR-MEM-OJ(ICV)($s_i$) model indeed has the largest number of stocks that have negatively significant statistics compared to other models especially for more recent years. This result is verified by both MSE and QLIKE loss functions. Though the HAR-MEM-OJ(RK)($s_i$) model performs better than the benchmark model when the test is based on the whole forecasting period with QLIKE, it cannot beat the benchmark model in other cas-

es. We recommend that use the HAR-MEM-OJ(ICV)($s_i$) model for the intraday volatility forecast at 10:00 to 12:00.

In the second time interval, 12:00 to 14:00, if we consider the whole forecasting period, the HAR-MEM-OJ(RK)($s_i^E$) model has comparable performance with the benchmark model when use the MSE, and it has better performance than the benchmark model when use the QLIKE. When test the forecasts every 252 days, there is not so much difference between the HAR-MEM-OJ(RK)($s_i^E$) model and the benchmark model, which is consistent with the result using MSE for whole forecasting period. The HAR-MEM-OJ(ICV)($s_i$) model has similar performance with the benchmark model in more recent years. The HAR-MEM-OJ(RK)($s_i$) model is inferior to the benchmark model. To sum up, all models except the HAR-MEM-OJ(RK)($s_i$) can be used for the intraday volatility forecast at 12:00 to 14:00.

In the third time interval, 14:00 to 16:00, the HAR-MEM-OJ(RK)($s_i$) model underperforms the benchmark model, if test every 252 days. This result is the same with forecasting result at second time interval. The other two models have comparable performance with the benchmark model with MSE, and are better than the benchmark model with QLIKE in more recent years.

In case investors want to know the intraday volatility of the next day at the end of the day, a comparison of models without overnight jump is needed. The benchmark model of this comparison is the HAR-MEM(ICV)($s_i^E$) model. From the Table 4.7 and Table 4.8, the HAR-MEM (ICV)($s_i$) model has better forecasting performance in the first two-hour volatility. In the second time interval, The HAR-MEM(RK)($s_i^E$) model and the HAR-MEM(ICV)($s_i$) model have comparable performance with the benchmark model, but the

HAR-MEM(RK)($s_i$) model is inferior to the benchmark model. In the last time interval, the HAR-MEM(RK)($s_i^E$) model and the HAR-MEM(ICV)($s_i$) model have similar result with the benchmark model if we use MSE, but these two models are better than the benchmark model if we use QLIKE for more recent years. The HAR-MEM(RK)($s_i$) model is inferior to other models at 14:00 to 16:00. The results of using the HAR-MEM model for daily component are similar to the comparison that uses the HAR-MEM-OJ model for the daily component in the intraday volatility forecasts.

In summary, the HAR-MEM model or the HAR-MEM-OJ model using ICV with $s_i$ is better in the first two-hour volatility forecasts. No model wins in the comparison at second and third time interval, and the models using RK with $s_i$ is less favorable than other three models.

Table 4.5: Intraday volatility forecasts comparison using the MSE loss function

| Time interval | Forecasting days | Negatively significant | | | Positively significant | | |
|---|---|---|---|---|---|---|---|
| | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | | RK | RK | ICV | RK | RK | ICV |
| 10:00-12:00 | 1-252 | 0 | 0 | 3 | 1 | 1 | 1 |
| | 253-504 | 2 | 1 | 8 | 0 | 1 | 1 |
| | 505-756 | 1 | 0 | 0 | 1 | 5 | 3 |
| | 757-1008 | 0 | 0 | 2 | 2 | 3 | 2 |
| | 1009-1260 | 0 | 0 | 3 | 2 | 5 | 0 |
| | 1261-end | 0 | 0 | 4 | 4 | 14 | 3 |
| | 1-end | 4 | 2 | 9 | 0 | 2 | 1 |
| 12:00-14:00 | 1-252 | 1 | 0 | 0 | 0 | 9 | 5 |
| | 253-504 | 1 | 0 | 0 | 0 | 4 | 2 |
| | 505-756 | 0 | 0 | 0 | 1 | 23 | 20 |
| | 757-1008 | 0 | 0 | 0 | 2 | 10 | 7 |
| | 1009-1260 | 1 | 0 | 2 | 0 | 12 | 1 |
| | 1261-end | 0 | 0 | 0 | 2 | 13 | 6 |
| | 1-end | 1 | 0 | 1 | 0 | 8 | 2 |
| 14:00-16:00 | 1-252 | 0 | 0 | 1 | 1 | 2 | 1 |
| | 253-504 | 0 | 0 | 2 | 0 | 0 | 0 |
| | 505-756 | 1 | 0 | 0 | 2 | 16 | 15 |
| | 757-1008 | 0 | 0 | 0 | 6 | 11 | 3 |
| | 1009-1260 | 1 | 0 | 2 | 5 | 15 | 2 |
| | 1261-end | 2 | 0 | 3 | 0 | 6 | 1 |
| | 1-end | 1 | 0 | 4 | 0 | 1 | 1 |

Note: This table counts the number of stocks that have either positively significant or negatively significant DMW statistics. The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy.

Table 4.6: Intraday volatility forecasts comparison using the QLIKE loss function

| Time interval | Forecasting days | Negatively significant | | | Positively significant | | |
|---|---|---|---|---|---|---|---|
| | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | | RK | RK | ICV | RK | RK | ICV |
| 10:00-12:00 | 1-252 | 6 | 3 | 7 | 0 | 1 | 1 |
| | 253-504 | 11 | 9 | 12 | 0 | 0 | 1 |
| | 505-756 | 2 | 0 | 1 | 0 | 3 | 4 |
| | 757-1008 | 2 | 0 | 3 | 1 | 2 | 1 |
| | 1009-1260 | 3 | 1 | 10 | 2 | 3 | 0 |
| | 1261-end | 2 | 0 | 5 | 0 | 2 | 0 |
| | 1-end | 16 | 11 | 14 | 0 | 1 | 0 |
| 12:00-14:00 | 1-252 | 1 | 1 | 2 | 0 | 5 | 5 |
| | 253-504 | 4 | 0 | 1 | 0 | 0 | 0 |
| | 505-756 | 0 | 0 | 0 | 0 | 10 | 11 |
| | 757-1008 | 2 | 0 | 2 | 1 | 5 | 3 |
| | 1009-1260 | 2 | 2 | 4 | 0 | 3 | 1 |
| | 1261-end | 3 | 0 | 4 | 0 | 8 | 4 |
| | 1-end | 14 | 0 | 6 | 0 | 6 | 3 |
| 14:00-16:00 | 1-252 | 4 | 0 | 8 | 2 | 2 | 0 |
| | 253-504 | 5 | 3 | 4 | 0 | 0 | 0 |
| | 505-756 | 0 | 0 | 0 | 2 | 9 | 7 |
| | 757-1008 | 2 | 1 | 0 | 0 | 5 | 1 |
| | 1009-1260 | 2 | 1 | 4 | 2 | 8 | 1 |
| | 1261-end | 9 | 5 | 7 | 1 | 1 | 0 |
| | 1-end | 20 | 2 | 13 | 0 | 0 | 0 |

Note: This table counts the number of stocks that have either positively significant or negatively significant DMW statistics. The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy.

Table 4.7: Intraday volatility forecasts comparison using the MSE loss function

| Time interval | Forecasting days | Negatively significant | | | Positively significant | | |
|---|---|---|---|---|---|---|---|
| | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | | RK | RK | ICV | RK | RK | ICV |
| 10:00-12:00 | 1-252 | 0 | 0 | 4 | 1 | 1 | 1 |
| | 253-504 | 2 | 0 | 8 | 0 | 1 | 1 |
| | 505-756 | 2 | 0 | 0 | 1 | 6 | 3 |
| | 757-1008 | 1 | 0 | 3 | 3 | 3 | 3 |
| | 1009-1260 | 0 | 0 | 3 | 3 | 7 | 0 |
| | 1261-end | 0 | 0 | 4 | 4 | 15 | 3 |
| | 1-end | 5 | 1 | 9 | 0 | 2 | 1 |
| 12:00-14:00 | 1-252 | 1 | 0 | 0 | 0 | 9 | 5 |
| | 253-504 | 0 | 0 | 0 | 0 | 4 | 1 |
| | 505-756 | 0 | 0 | 0 | 2 | 26 | 20 |
| | 757-1008 | 0 | 0 | 1 | 2 | 12 | 7 |
| | 1009-1260 | 1 | 0 | 3 | 0 | 11 | 1 |
| | 1261-end | 0 | 0 | 0 | 1 | 14 | 6 |
| | 1-end | 1 | 0 | 1 | 0 | 10 | 4 |
| 14:00-16:00 | 1-252 | 0 | 0 | 1 | 0 | 2 | 1 |
| | 253-504 | 0 | 0 | 2 | 0 | 0 | 0 |
| | 505-756 | 1 | 0 | 0 | 2 | 17 | 15 |
| | 757-1008 | 0 | 0 | 0 | 4 | 11 | 4 |
| | 1009-1260 | 1 | 0 | 2 | 5 | 15 | 2 |
| | 1261-end | 3 | 0 | 2 | 1 | 6 | 1 |
| | 1-end | 1 | 0 | 4 | 1 | 1 | 1 |

Note: This table counts the number of stocks that have either positively significant or negatively significant DMW statistics. The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy.

Table 4.8: Intraday volatility forecasts comparison using the QLIKE loss function

| Time interval | Forecasting days | Negatively significant | | | Positively significant | | |
|---|---|---|---|---|---|---|---|
| | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | | RK | RK | ICV | RK | RK | ICV |
| 10:00-12:00 | 1-252 | 5 | 4 | 7 | 0 | 1 | 1 |
| | 253-504 | 11 | 9 | 12 | 0 | 0 | 1 |
| | 505-756 | 2 | 0 | 1 | 1 | 4 | 4 |
| | 757-1008 | 2 | 0 | 3 | 1 | 2 | 1 |
| | 1009-1260 | 3 | 1 | 10 | 2 | 3 | 0 |
| | 1261-end | 1 | 0 | 5 | 0 | 1 | 0 |
| | 1-end | 18 | 10 | 14 | 0 | 1 | 0 |
| 12:00-14:00 | 1-252 | 2 | 1 | 2 | 0 | 6 | 5 |
| | 253-504 | 6 | 0 | 1 | 0 | 0 | 0 |
| | 505-756 | 0 | 0 | 0 | 0 | 12 | 11 |
| | 757-1008 | 2 | 0 | 2 | 1 | 5 | 3 |
| | 1009-1260 | 4 | 2 | 4 | 0 | 3 | 1 |
| | 1261-end | 1 | 0 | 2 | 0 | 8 | 5 |
| | 1-end | 14 | 0 | 6 | 0 | 6 | 3 |
| 14:00-16:00 | 1-252 | 4 | 1 | 8 | 1 | 2 | 0 |
| | 253-504 | 5 | 3 | 4 | 0 | 0 | 0 |
| | 505-756 | 1 | 0 | 0 | 0 | 10 | 7 |
| | 757-1008 | 0 | 0 | 0 | 0 | 6 | 1 |
| | 1009-1260 | 2 | 0 | 4 | 1 | 7 | 1 |
| | 1261-end | 9 | 5 | 6 | 1 | 1 | 0 |
| | 1-end | 18 | 4 | 12 | 0 | 0 | 0 |

Note: This table counts the number of stocks that have either positively significant or negatively significant DMW statistics. The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy.

# Chapter 5

# Conclusion

In this paper, we follow a multiplicative component model for intraday volatility and compare 12 daily models and 2 ways of estimating periodicity component among 30 stocks. We introduce a new way to estimate intraday periodicity component. For daily volatility forecasting, our main conclusion is that HAR-MEM-OJ and HAR-MEM perform better than other models while also capturing long memory property of volatility. Overnight jump slightly improves daily volatility forecasts. For intraday volatility model, our main recommendation would be using HAR-MEM-OJ (ICV) as the daily component specification and $s_i$ as the periodicity component for the first 2-hour volatility forecasts. But for the second and third period, it is hard to decide which one is the best among intraday volatility models. If forecasting intraday volatility at the end of the day, the HAR-MEM (ICV) with $s_i$ has the relatively better forecasting performance for the first two hours than other models.

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# Appendix A

# Estimation of volatility

We consider both realized kernel and ACD-ICV estimators for this study. The reason for choosing these two estimators is that RK method is robust to some microstructure noise, and has been proved succeedful theoretically and empirically, but the simulation result of ACD-ICV method shows ACD-ICV method performs better than RK. Therefore, comparison between these two estimators empirically is an interesting exercise.

## A.1 Realized kernel

For realized kernel, we follow Barndorff-Nielsen et al.'s (2008) recommendation for the specification of estimator. The estimator is expressed as

$$K(x) = \sum_{h=-H}^{H} k(\frac{h}{H+1})\gamma_h \qquad \text{and} \qquad \gamma_h = \sum_{j=|h|+1}^{n} x_j x_{j-h} \tag{A.1}$$

where $k(x)$ is the Parzen kernel function. $\gamma_h$ is the autocovariance of return and $x_j$ is the $j$th return. H is the bandwidth. The kernel estimator smoothes the realized autocovariances with the weight function. The kernel function is described as

$$k(x) = \begin{cases} 1 - 6x^2 + 6x^3 & 0 \leq x \leq 1/2 \\ 2(1-x)^3 & 1/2 \leq x \leq 1 \\ 0 & x > 1 \end{cases} \tag{A.2}$$

The choice of bandwidth is the optimal bandwidth, $H^*$, where

$$H^* = c^* \xi^{4/5} n^{3/5} \qquad c^* = 3.5134 \qquad \xi^2 = \frac{\omega^2}{\sqrt{T \int_0^T \sigma_\mu^4 d\mu}} = \frac{\omega^2}{\widehat{IV}} \tag{A.3}$$

$\omega^2$ is estimated by

$$\omega^2 = \frac{1}{q} \sum_{i=1}^{q} \omega_{(i)}^2 \qquad \omega_{(i)}^2 = \frac{RV_{dense}^{(i)}}{2n_{(i)}} \tag{A.4}$$

$RV_{dense}^{(i)}$ is the realized variance starting from $i$th trade and sampled every $q$th trade. We select $q$ so that every $q$th observation is 2 minutes apart on average. $\omega^2$ is the average of these $q$ estimates. $\widehat{IV}$ is estimated by the subsampled realized variance based on 20 minutes returns. We calculate 1200 realized variances by varying the start point from 1 to 1200. $\widehat{IV}$ is the average of these 1200 realized variances.

## A.2 ACD-ICV

The ACD-ICV method estimates volatility by integrating instantaneous return variance per unit time derived from ACD model. The first step is to estimate an ACD model. In this paper, we adopt simple ACD (1, 1) with unit exponential distribution for the error term. The ACD (1, 1) can be described as following process,

$$x_i = \psi_i \varepsilon_i \qquad \text{and} \qquad \varepsilon_i \sim exp(1), \tag{A.5}$$

$$\psi_i = \omega + \alpha x_{i-1} + \beta \psi_{i-1} \tag{A.6}$$

where $x_i = t_i - t_{i-1}$ is the price duration of $i$th price event. A price event is defined as the logarithmic stock price first moves by an amount $\delta$ or more, whether upwards or downwards. $\psi_i = E(x_i|\Psi_{i-1})$ is the conditional expectation of the price duration.

Tse and Yang (2012) show that integrated conditional variance over the interval ($t_0$, $t_N$) is given by

$$ICV = \sum_{i=0}^{N-1} \int_{t_i}^{t_{i+1}} \sigma^2(t|\psi_i)dt = \delta^2 \sum_{i=0}^{N-1} \frac{t_{i+1} - t_i}{\psi_{i+1}} \tag{A.7}$$

From ACD model, we can obtain estimate of $\psi_{i+1}$. This estimator is weighted sum of instantaneous conditional variance.

Volatilities are estimated year by year, because transactions are less frequent in early years and more frequent in recent years. For the first 4 years, we choose $\delta$ so that the mean duration is around 30 minutes. For 1997 to 2000, the choice of $\delta$ would make average price duration around 15 minutes. For 2001 to 2004, the average price duration would

be around 10 minutes. For the last 3 years, we choose $\delta$ so that average price duration is around 5 minutes.

# Appendix B

# Tables

Table B.1: DMW statistics of daily volatility model comparison with QLIKE loss function using RK as volatility measure

| Stock | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IBM | 5.07 | 4.66 | -1.14 | 1.24 | 0.80 | 6.70 | 6.38 | 0.17 | -0.93 | 1.36 | 0.82 |
| GE | 4.19 | 3.37 | -0.88 | 0.36 | -0.93 | 5.09 | 4.28 | 1.06 | -1.35 | 0.25 | -0.67 |
| MO | 5.24 | 4.64 | 0.11 | 0.04 | -0.61 | 5.59 | 5.15 | 0.37 | -0.11 | 0.14 | -0.38 |
| MRK | 0.21 | 0.23 | -0.99 | 0.31 | 0.90 | 0.28 | 0.25 | 1.47 | -0.70 | 0.07 | 0.58 |
| KO | 6.25 | 3.86 | -6.39 | -3.21 | -4.78 | 6.53 | 4.98 | -0.99 | -2.66 | -3.27 | -4.78 |
| PFE | 2.87 | -1.13 | -1.95 | 1.37 | -1.83 | 2.63 | -0.67 | 0.20 | -1.78 | 1.40 | -1.69 |
| JNJ | 5.49 | 3.96 | -5.13 | -4.32 | -3.79 | 5.95 | 4.77 | 1.74 | -1.36 | -3.46 | -3.77 |
| AIG | 0.89 | 0.32 | 1.11 | 1.60 | -0.50 | 6.33 | 6.07 | 6.11 | 5.85 | 1.63 | 1.63 |
| PG | 7.29 | 6.39 | -2.86 | -5.45 | -3.70 | 7.96 | 7.19 | 1.83 | 0.19 | -5.44 | -3.72 |
| WMT | 6.48 | 6.29 | 1.18 | -0.30 | -0.59 | 7.16 | 7.03 | 1.17 | -0.01 | -0.16 | -0.34 |
| JPM | 5.57 | 4.93 | -2.18 | 0.02 | -1.38 | 5.97 | 5.28 | 1.38 | -1.26 | 0.50 | -1.01 |
| PEP | 7.10 | 6.09 | -6.95 | -3.93 | -4.52 | 8.26 | 7.43 | 1.03 | -0.70 | -4.37 | -4.50 |
| DD | 3.10 | 1.08 | -3.55 | -2.93 | -3.26 | 4.43 | 3.01 | 0.10 | -1.80 | -2.95 | -3.00 |
| DIS | 2.82 | 2.20 | -3.95 | -1.67 | -2.10 | 3.57 | 3.03 | 0.30 | -1.48 | -1.46 | -1.81 |
| HD | 3.36 | 2.42 | 2.17 | -0.16 | -2.69 | 3.92 | 3.35 | 1.54 | -1.00 | 0.30 | -1.64 |
| BA | 1.78 | 1.24 | -2.93 | 0.25 | -0.67 | 2.64 | 2.24 | -0.22 | -0.71 | 0.37 | -0.63 |
| MMM | 3.40 | -0.69 | -2.10 | -0.15 | -3.00 | 3.63 | 0.97 | -0.17 | -2.39 | -0.17 | -2.88 |
| AXP | 2.50 | 2.32 | -0.32 | 1.28 | 0.48 | 3.83 | 3.64 | -0.30 | -0.72 | 1.13 | 0.55 |
| T | 4.44 | 2.71 | 3.50 | 2.30 | 0.85 | 4.28 | 3.45 | 1.63 | -0.63 | 2.74 | 1.30 |
| MCD | 2.48 | -0.26 | -3.07 | -0.93 | -3.30 | 2.47 | 0.59 | -0.69 | -3.13 | -1.28 | -3.39 |
| SLB | -0.48 | -2.03 | -2.11 | 1.43 | -0.35 | 0.49 | -0.79 | 0.46 | -1.46 | 1.22 | 0.08 |
| TXN | 4.27 | 4.25 | -4.01 | 1.18 | 0.64 | 4.23 | 4.20 | 1.56 | 1.08 | 1.24 | 0.97 |
| DOW | 4.08 | -0.73 | -1.24 | 0.81 | -1.09 | 4.13 | -0.20 | 1.00 | -1.11 | 1.37 | -0.97 |
| ABT | 3.85 | 0.45 | -1.52 | -1.17 | -1.64 | 3.80 | 1.82 | -1.24 | -1.93 | -1.32 | -1.41 |
| CL | 4.98 | 0.06 | -3.22 | -3.04 | -4.10 | 5.72 | 2.18 | 0.24 | -2.63 | -3.07 | -3.91 |
| BAC | 4.78 | 4.78 | -2.75 | 3.46 | 3.56 | 6.44 | 6.43 | 0.39 | 0.21 | 3.55 | 3.62 |
| UTX | 4.52 | -0.53 | 0.45 | -2.41 | -1.34 | 3.03 | -0.22 | -1.05 | -1.11 | -2.54 | -1.48 |
| EMR | 3.60 | -1.58 | -1.46 | -0.93 | -2.50 | 3.29 | -0.31 | -1.22 | -2.23 | 5.24 | 5.19 |
| MDT | 6.92 | 5.06 | -1.28 | -0.53 | -1.22 | 8.30 | 7.12 | 0.15 | -0.79 | -0.52 | -0.37 |
| UNH | 3.35 | 0.68 | -3.71 | 4.27 | 0.43 | 4.71 | 2.59 | 0.91 | -2.31 | 4.31 | 1.19 |

Note: Model 1 is HAR. Model 2 is HAR-OJ. Model 3 is HAR-MEM-OJ. Model 4 is HAR-MEM-$r$. Model 5 is HAR-MEM-$r$-OJ. Model 6 is W-HAR. Model 7 is W-HAR-OJ. Model 8 is W-HAR-MEM. Model 9 is W-HAR-MEM-OJ. Model 10 is W-HAR-MEM-$r$. Model 11 is W-HAR-MEM-$r$-OJ. The benchmark model is the HAR-MEM model. The volatility proxy is $r_t^2$.

Table B.2: DMW statistics of daily volatility model comparison with MSE loss function using RK as volatility measure

| Stock | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IBM | -1.38 | -0.90 | -2.15 | 0.69 | 1.67 | 1.45 | 1.57 | 0.39 | 1.61 | 0.91 | 1.78 |
| GE | -0.20 | 0.29 | -1.85 | -1.35 | 1.26 | 0.33 | 0.63 | -0.79 | 0.70 | -1.29 | 1.33 |
| MO | -0.80 | 1.09 | 0.69 | 2.48 | 1.29 | -0.27 | 1.17 | -0.70 | 1.08 | 2.34 | 1.25 |
| MRK | -1.24 | 0.95 | -0.03 | -0.53 | 1.01 | -1.02 | 0.97 | 0.30 | 1.02 | -0.09 | 1.03 |
| KO | 0.98 | 0.82 | -3.27 | -0.44 | 0.46 | 1.14 | 1.05 | -1.14 | -0.60 | -1.04 | 0.43 |
| PFE | 0.37 | -1.15 | -0.93 | 2.55 | -0.24 | 0.21 | -1.14 | -0.60 | -1.15 | 2.20 | -0.83 |
| JNJ | -0.67 | 0.92 | -0.05 | -2.46 | 0.95 | -0.51 | 0.96 | -1.08 | 1.00 | -2.49 | 0.90 |
| AIG | 0.36 | -0.89 | 0.69 | 1.09 | 1.08 | 2.46 | 1.98 | 2.05 | 1.75 | 1.09 | 1.73 |
| PG | 2.37 | 1.01 | 0.99 | -3.65 | 1.00 | 2.30 | 1.02 | -0.08 | 1.01 | -3.61 | 1.00 |
| WMT | 1.40 | 1.59 | -1.29 | -1.28 | -0.81 | 1.30 | 1.47 | 1.25 | 0.55 | -1.33 | -0.76 |
| JPM | 1.03 | 0.91 | -0.33 | 0.71 | -0.66 | 0.95 | 0.09 | 0.78 | -1.11 | 0.71 | -0.42 |
| PEP | 0.88 | 0.74 | -0.40 | -1.69 | 0.44 | 1.60 | 1.29 | -0.39 | 1.03 | -2.83 | 0.30 |
| DD | 1.07 | 0.51 | -0.55 | -0.18 | -0.21 | 1.51 | 1.20 | -0.76 | -0.92 | -0.61 | -0.12 |
| DIS | -0.72 | 0.12 | -1.57 | -1.88 | 0.92 | -0.82 | -0.55 | 0.74 | 0.91 | -1.82 | 0.76 |
| HD | 1.55 | 1.38 | -0.49 | 1.31 | 1.65 | 1.56 | 1.42 | 0.92 | 1.06 | 1.59 | 1.77 |
| BA | 0.63 | 0.81 | -0.27 | -1.13 | 0.89 | 0.70 | 0.84 | -1.42 | 0.90 | -1.34 | 0.83 |
| MMM | 0.60 | -1.11 | -2.08 | -1.81 | -0.64 | 0.82 | -0.06 | -1.18 | -2.24 | -1.81 | -1.23 |
| AXP | -1.74 | -1.47 | -1.69 | -0.41 | 1.67 | 0.13 | 0.20 | -0.41 | 1.19 | -0.41 | 0.98 |
| T | 0.14 | -0.88 | -1.77 | 1.46 | 0.47 | 0.66 | -0.09 | -1.94 | -0.74 | 1.27 | 0.36 |
| MCD | -0.81 | 0.73 | -1.27 | -1.13 | 0.36 | -0.36 | 0.80 | -1.22 | 0.28 | -0.87 | 0.48 |
| SLB | -0.58 | -1.81 | -0.60 | 0.76 | -0.92 | 0.59 | -0.67 | -0.06 | -1.43 | 0.60 | -0.63 |
| TXN | -0.27 | -0.19 | -2.10 | 1.34 | 1.62 | -0.27 | -0.28 | 1.65 | 1.51 | 1.29 | 1.49 |
| DOW | 0.67 | -0.98 | -1.90 | 2.61 | -0.94 | 0.46 | -1.00 | 0.83 | -1.04 | 2.14 | -0.92 |
| ABT | -0.36 | -0.27 | -0.74 | -0.65 | 1.17 | -0.16 | -0.29 | 1.03 | 0.28 | -0.18 | 1.13 |
| CL | 2.29 | 0.57 | -2.10 | -2.48 | 0.31 | 3.35 | 1.31 | -0.37 | -0.16 | -2.53 | -0.11 |
| BAC | -0.16 | 0.07 | -2.26 | 2.67 | 2.93 | 1.25 | 1.47 | -0.74 | 1.59 | 2.67 | 2.94 |
| UTX | 1.55 | -0.99 | 0.73 | -1.61 | -1.00 | 1.75 | -0.98 | -1.70 | -1.03 | -1.73 | -1.04 |
| EMR | 1.26 | -1.59 | -1.02 | 0.55 | -2.17 | 2.17 | -0.61 | -1.47 | -2.27 | 2.90 | 2.51 |
| MDT | 1.82 | 2.09 | -1.71 | 0.04 | 0.94 | 3.11 | 3.15 | -0.38 | 1.45 | 0.19 | 1.29 |
| UNH | 1.00 | -0.71 | -3.24 | 3.07 | 1.38 | 2.20 | 0.77 | 0.16 | -2.07 | 3.03 | 1.63 |

Note: Model 1 is HAR. Model 2 is HAR-OJ. Model 3 is HAR-MEM-OJ. Model 4 is HAR-MEM-$r$. Model 5 is HAR-MEM-$r$-OJ. Model 6 is W-HAR. Model 7 is W-HAR-OJ. Model 8 is W-HAR-MEM. Model 9 is W-HAR-MEM-OJ. Model 10 is W-HAR-MEM-$r$. Model 11 is W-HAR-MEM-$r$-OJ. The benchmark model is the HAR-MEM model. The volatility proxy is $r_t^2$.

Table B.3: DMW statistics of daily volatility model comparison with QLIKE loss function using ICV as volatility measure

| Stock | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IBM | 0.85 | 0.48 | -1.30 | 2.16 | 1.57 | 3.36 | 2.86 | 1.75 | 0.60 | 2.23 | 1.62 |
| GE | 1.00 | 0.51 | -1.71 | 0.94 | 0.00 | 2.15 | 1.59 | 1.34 | -0.62 | 0.91 | 0.18 |
| MO | -0.50 | -1.08 | -0.86 | -0.24 | -0.31 | -0.35 | -0.81 | 1.44 | -0.45 | -0.12 | -0.20 |
| MRK | -1.85 | -1.07 | -0.27 | -0.88 | -1.14 | -0.49 | -0.32 | 1.68 | 1.47 | -0.83 | -1.02 |
| KO | 4.13 | 1.21 | -1.83 | 4.58 | 1.30 | 4.07 | 1.87 | -0.94 | -2.39 | 4.52 | 1.30 |
| PFE | 0.69 | -1.27 | -1.51 | 1.79 | -1.03 | 0.00 | -1.25 | -0.88 | -1.49 | 1.71 | -1.01 |
| JNJ | -0.86 | -0.96 | -1.47 | 3.74 | 1.64 | -0.07 | -0.42 | 2.38 | -0.96 | 3.93 | 1.40 |
| AIG | 0.28 | -1.26 | -1.48 | -0.29 | -0.81 | 0.86 | -0.74 | 1.68 | -1.00 | -0.26 | -0.86 |
| PG | 1.47 | 1.44 | 0.33 | 3.84 | 2.36 | 2.56 | 2.28 | 1.96 | 1.16 | 3.82 | 2.32 |
| WMT | 1.78 | 1.62 | -0.32 | 4.27 | 4.26 | 1.73 | 1.61 | 0.52 | 0.35 | 4.18 | 4.14 |
| JPM | 1.06 | 0.06 | -2.32 | 2.99 | 0.00 | 1.33 | 0.44 | 0.55 | -1.49 | 2.84 | 0.17 |
| PEP | 5.54 | 4.89 | -2.11 | 0.86 | -0.53 | 5.86 | 5.34 | 2.55 | -0.50 | 1.25 | -0.38 |
| DD | -0.22 | -1.58 | -1.74 | 3.35 | 1.57 | 1.01 | -0.31 | 1.77 | -0.76 | 3.30 | 2.09 |
| DIS | -1.21 | -1.51 | -1.37 | 3.75 | -0.49 | 0.27 | 0.02 | -0.10 | -1.20 | 3.58 | -0.59 |
| HD | -0.16 | -0.41 | -2.16 | 2.76 | 0.71 | -0.13 | -0.28 | 0.61 | 0.03 | 3.00 | 0.65 |
| BA | -3.12 | -2.69 | 0.24 | 0.68 | -0.10 | -1.82 | -1.61 | 1.03 | 0.47 | 0.71 | -0.07 |
| MMM | -1.58 | -2.88 | -2.72 | 0.63 | -0.82 | -0.06 | -1.68 | -0.19 | -2.17 | 0.58 | -0.79 |
| AXP | -2.97 | -2.82 | -0.55 | -1.23 | -1.45 | -1.41 | -1.37 | 1.07 | -0.49 | -1.23 | -1.53 |
| T | -2.53 | -3.22 | -2.71 | 3.60 | 2.67 | -0.88 | -1.60 | 2.20 | -1.07 | 3.78 | 2.71 |
| MCD | -2.25 | -3.30 | -3.00 | 0.02 | -1.45 | -2.29 | -3.13 | 0.60 | -2.60 | 0.01 | -1.44 |
| SLB | -1.58 | -2.65 | -1.83 | 0.53 | -0.08 | -0.59 | -1.54 | 0.06 | -1.45 | 0.56 | 0.13 |
| TXN | 0.67 | 0.74 | -1.52 | 3.14 | 2.88 | 0.24 | 0.19 | 0.63 | -0.13 | 3.20 | 2.92 |
| DOW | 1.29 | -1.12 | -1.32 | 1.67 | -0.16 | 1.72 | -1.06 | 0.10 | -1.27 | 1.72 | -0.16 |
| ABT | 0.04 | -1.21 | -1.29 | 1.40 | -0.08 | 0.80 | -0.93 | -0.89 | -1.43 | 1.36 | -0.09 |
| CL | 0.14 | -1.79 | -1.98 | 1.53 | -0.60 | 0.34 | -1.51 | 0.51 | -2.20 | 1.80 | -0.57 |
| BAC | 1.04 | 1.07 | 0.07 | 2.85 | 2.89 | 1.15 | 1.25 | 0.15 | 0.18 | 2.88 | 2.92 |
| UTX | 1.31 | -0.98 | -1.01 | -0.24 | -0.96 | 1.26 | -0.96 | -0.82 | -1.01 | -0.29 | -0.98 |
| EMR | 0.65 | -1.60 | -1.93 | -0.10 | -1.68 | 1.42 | -0.96 | 0.13 | -1.76 | -0.16 | -1.77 |
| MDT | 1.12 | -0.89 | -1.58 | 2.79 | 2.39 | 2.40 | 0.38 | 2.08 | -0.63 | 2.96 | 2.73 |
| UNH | -2.28 | -2.46 | -2.16 | 0.48 | -0.88 | -1.89 | -2.22 | 0.98 | -2.03 | 0.47 | -0.82 |

Note: Model 1 is HAR. Model 2 is HAR-OJ. Model 3 is HAR-MEM-OJ. Model 4 is HAR-MEM-$r$. Model 5 is HAR-MEM-$r$-OJ. Model 6 is W-HAR. Model 7 is W-HAR-OJ. Model 8 is W-HAR-MEM. Model 9 is W-HAR-MEM-OJ. Model 10 is W-HAR-MEM-$r$. Model 11 is W-HAR-MEM-$r$-OJ. The benchmark model is the HAR-MEM model. The volatility proxy is $r_t^2$.

Table B.4: DMW statistics of daily volatility model comparison with MSE loss function using ICV as volatility measure

| Stock | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IBM | -0.24 | 0.19 | 1.06 | 1.40 | 1.90 | 2.50 | 2.47 | 2.20 | 2.23 | 1.75 | 1.94 |
| GE | 0.87 | 0.65 | -0.85 | 0.48 | 1.27 | 1.03 | 0.76 | -0.97 | -0.92 | 0.41 | 1.39 |
| MO | 0.22 | 1.33 | 1.28 | -0.91 | 1.18 | 0.16 | 1.25 | 0.39 | 1.32 | -0.84 | 1.17 |
| MRK | 0.44 | 1.02 | 0.99 | -0.77 | 1.00 | -0.47 | 0.89 | -0.44 | 0.99 | -0.80 | 1.01 |
| KO | 1.07 | 0.60 | 0.20 | 1.09 | 1.65 | 1.02 | 0.65 | -1.04 | -0.98 | 1.06 | 1.66 |
| PFE | 1.52 | -0.98 | -1.12 | 0.62 | 0.39 | 0.21 | -1.05 | -1.26 | -1.13 | 0.40 | 0.24 |
| JNJ | 0.79 | 0.94 | 0.94 | 4.04 | 1.04 | 0.99 | 0.99 | 0.90 | 0.96 | 3.98 | 1.05 |
| AIG | 1.47 | -0.82 | -1.28 | -1.43 | -0.80 | 1.56 | -0.54 | 1.83 | -1.13 | -1.42 | -0.75 |
| PG | 0.33 | 1.00 | 1.00 | 2.95 | 1.01 | 1.25 | 1.03 | 0.99 | 1.00 | 2.96 | 1.01 |
| WMT | 0.72 | 1.30 | 1.20 | 0.86 | 1.26 | 1.41 | 1.71 | 0.45 | 1.34 | 0.87 | 1.23 |
| JPM | 1.02 | 0.15 | -1.20 | -0.78 | -1.05 | 0.13 | -1.02 | -1.07 | -1.16 | -0.78 | -1.03 |
| PEP | 0.12 | 0.34 | 0.52 | -0.21 | 0.93 | 0.48 | 0.51 | 0.96 | 0.58 | 0.07 | 0.90 |
| DD | 0.60 | 0.06 | -0.86 | 1.35 | 0.72 | 0.95 | 0.35 | 0.08 | -0.77 | 1.49 | 1.29 |
| DIS | -0.11 | 0.03 | 0.73 | 0.84 | 1.15 | 0.60 | 0.60 | 0.33 | 0.11 | 0.99 | 1.14 |
| HD | 1.74 | 1.72 | -0.17 | 0.76 | 1.76 | 2.03 | 2.01 | 1.56 | 0.97 | 1.25 | 1.54 |
| BA | -0.10 | 0.64 | 0.71 | 1.27 | 1.10 | 0.97 | 1.02 | 1.54 | 0.83 | 1.37 | 1.11 |
| MMM | -0.49 | -1.84 | -2.21 | -0.12 | 0.57 | 0.80 | -0.25 | -0.38 | -1.73 | -0.19 | 0.41 |
| AXP | 1.00 | 0.36 | -0.26 | -0.22 | 1.27 | 1.57 | 0.89 | 1.36 | -0.05 | -0.27 | 1.19 |
| T | -1.06 | -1.47 | -0.70 | 2.00 | 1.04 | 0.06 | -0.55 | 0.49 | -0.56 | 2.08 | 0.97 |
| MCD | 0.12 | -0.90 | -1.53 | 1.23 | 1.02 | 0.03 | -0.97 | -0.34 | -1.58 | 1.20 | 1.02 |
| SLB | -0.29 | -1.20 | -1.91 | 0.80 | -0.28 | 1.07 | 0.16 | -0.63 | -1.62 | 0.61 | -0.15 |
| TXN | 2.57 | 2.54 | -1.18 | 0.27 | 1.06 | 1.98 | 1.96 | 1.19 | -0.17 | 0.31 | 1.05 |
| DOW | 1.43 | -1.01 | -1.06 | 0.54 | -0.94 | 2.06 | -0.98 | 0.24 | -1.05 | 0.66 | -0.94 |
| ABT | -0.29 | -0.72 | -0.60 | 1.39 | 1.25 | 0.54 | -0.61 | 0.55 | -0.59 | 1.27 | 1.26 |
| CL | 0.94 | -0.15 | -1.12 | 1.21 | 1.25 | 1.56 | 0.29 | -0.30 | -1.95 | 1.19 | 1.25 |
| BAC | -0.15 | 0.21 | 1.51 | 0.78 | 0.92 | 0.98 | 1.16 | 1.66 | 2.23 | 0.87 | 0.98 |
| UTX | 1.91 | -0.94 | -1.01 | -1.39 | -1.03 | 1.77 | -0.89 | -0.41 | -1.01 | -1.39 | -1.04 |
| EMR | 1.47 | 0.44 | -2.03 | -0.29 | -1.36 | 1.58 | 0.66 | 0.46 | -1.79 | -0.36 | -1.45 |
| MDT | 2.21 | 1.49 | -0.44 | 0.74 | 1.52 | 2.59 | 2.09 | 2.68 | 1.19 | 0.96 | 1.67 |
| UNH | -1.89 | -2.22 | -2.11 | 1.39 | 0.67 | -1.03 | -1.62 | 0.44 | -2.22 | 1.39 | 0.49 |

Note: Model 1 is HAR. Model 2 is HAR-OJ. Model 3 is HAR-MEM-OJ. Model 4 is HAR-MEM-$r$. Model 5 is HAR-MEM-$r$-OJ. Model 6 is W-HAR. Model 7 is W-HAR-OJ. Model 8 is W-HAR-MEM. Model 9 is W-HAR-MEM-OJ. Model 10 is W-HAR-MEM-$r$. Model 11 is W-HAR-MEM-$r$-OJ. The benchmark model is HAR-MEM model. The volatility proxy is $r_t^2$.

Table B.5: DMW statistics of daily volatility comparison of RK and ICV with QLIKE loss function

| Stock | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|---|---|
| IBM | -1.14 | 0.26 | 0.12 | 1.24 | 0.80 | 3.06 | 2.52 |
| GE | -0.88 | -1.21 | -1.71 | 0.36 | -0.93 | -0.48 | -0.98 |
| MO | 0.11 | 0.24 | 0.04 | 0.04 | -0.61 | 0.07 | -0.05 |
| MRK | -0.99 | 0.82 | 0.79 | 0.31 | 0.90 | -0.30 | -0.90 |
| KO | -6.39 | -1.83 | -2.25 | -3.21 | -4.78 | 2.58 | -0.29 |
| PFE | -1.95 | 0.39 | -1.75 | 1.37 | -1.83 | 3.33 | -1.23 |
| JNJ | -5.13 | -1.78 | -2.46 | -4.32 | -3.79 | 2.78 | 0.44 |
| AIG | 1.11 | 2.26 | 2.05 | 1.60 | -0.50 | 2.34 | 1.59 |
| PG | -2.86 | -2.08 | -1.99 | -5.45 | -3.70 | 0.06 | 0.28 |
| WMT | 1.18 | -3.73 | -3.74 | -0.30 | -0.59 | -1.19 | -1.15 |
| JPM | -2.18 | 0.39 | 0.06 | 0.02 | -1.38 | 1.80 | 0.56 |
| PEP | -6.95 | -3.04 | -3.48 | -3.93 | -4.52 | -2.09 | -2.84 |
| DD | -3.55 | -3.43 | -3.80 | -2.93 | -3.26 | -0.84 | -1.69 |
| DIS | -3.95 | 0.41 | 0.25 | -1.67 | -2.10 | 2.26 | -0.07 |
| HD | 2.17 | -0.88 | -0.97 | -0.16 | -2.69 | 2.06 | -0.04 |
| BA | -2.93 | 1.57 | 1.55 | 0.25 | -0.67 | 3.24 | 2.44 |
| MMM | -2.10 | 0.38 | -0.14 | -0.15 | -3.00 | 1.77 | -0.77 |
| AXP | -0.32 | 2.97 | 2.80 | 1.28 | 0.48 | 2.77 | 2.37 |
| T | 3.50 | 0.26 | -0.13 | 2.30 | 0.85 | 4.55 | 3.61 |
| MCD | -3.07 | 0.53 | 0.07 | -0.93 | -3.30 | 0.84 | -0.71 |
| SLB | -2.11 | 1.92 | 1.63 | 1.43 | -0.35 | 3.86 | 2.30 |
| TXN | -4.01 | 0.55 | 0.48 | 1.18 | 0.64 | 5.44 | 5.00 |
| DOW | -1.24 | 0.95 | -0.53 | 0.81 | -1.09 | 4.72 | 0.53 |
| ABT | -1.52 | 0.61 | -0.06 | -1.17 | -1.64 | 2.48 | 0.64 |
| CL | -3.22 | -1.58 | -2.36 | -3.04 | -4.10 | -0.65 | -2.56 |
| BAC | -2.75 | -1.45 | -1.44 | 3.46 | 3.56 | 2.19 | 2.22 |
| UTX | 0.45 | 1.39 | -0.01 | -2.41 | -1.34 | 4.39 | -0.40 |
| EMR | -1.46 | 1.28 | 0.69 | -0.93 | -2.50 | 2.23 | -0.65 |
| MDT | -1.28 | -0.88 | -1.16 | -0.53 | -1.22 | 3.16 | 2.54 |
| UNH | -3.71 | 1.97 | 1.78 | 4.27 | 0.43 | 6.24 | 1.70 |

Note: This table compares RK and ACD-ICV method. The benchmark model is HAR-MEM with RK as the volatility measure. $r_t^2$ is the proxy. Model 1 is HAR-MEM-OJ with RK. Model 2 is HAR-MEM-$r$ with RK. Model 3 is HAR-MEM-$r$-OJ with RK. Model 4 is HAR-MEM with ICV. Model 5 is HAR-MEM-OJ with ICV. Model 6 is HAR-MEM-$r$ with ICV. Model 7 is the HAR-MEM-$r$-OJ with ICV.

Table B.6: DMW statistics of daily volatility comparison of RK and ICV with MSE loss function

| Stock | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|---|---|
| IBM | -2.15 | -0.64 | -0.57 | 0.69 | 1.67 | 0.33 | 1.54 |
| GE | -1.85 | -0.45 | -0.61 | -1.35 | 1.26 | -0.35 | 1.20 |
| MO | 0.69 | -1.22 | 0.34 | 2.48 | 1.29 | -1.91 | 1.16 |
| MRK | -0.03 | 0.04 | 0.19 | -0.53 | 1.01 | -0.21 | 1.00 |
| KO | -3.27 | -0.38 | -0.37 | -0.44 | 0.46 | 0.05 | 1.28 |
| PFE | -0.93 | 0.43 | -0.67 | 2.55 | -0.24 | 1.13 | 0.48 |
| JNJ | -0.05 | -1.18 | -0.59 | -2.46 | 0.95 | -0.56 | 0.98 |
| AIG | 0.69 | 1.24 | 1.16 | 1.09 | 1.08 | 1.09 | 1.22 |
| PG | 0.99 | -1.29 | 0.97 | -3.65 | 1.00 | -0.35 | 1.01 |
| WMT | -1.29 | -0.20 | -0.15 | -1.28 | -0.81 | 0.02 | 0.13 |
| JPM | -0.33 | 0.58 | 0.52 | 0.71 | -0.66 | 0.54 | -0.29 |
| PEP | -0.40 | -0.54 | -0.28 | -1.69 | 0.44 | -0.75 | 0.37 |
| DD | -0.55 | -0.07 | -0.12 | -0.18 | -0.21 | 0.29 | 0.21 |
| DIS | -1.57 | -1.05 | -0.98 | -1.88 | 0.92 | -0.93 | 1.02 |
| HD | -0.49 | 0.22 | 0.21 | 1.31 | 1.65 | 0.67 | 1.42 |
| BA | -0.27 | 0.87 | 0.88 | -1.13 | 0.89 | 1.70 | 1.11 |
| MMM | -2.08 | -0.28 | -0.39 | -1.81 | -0.64 | -0.48 | 0.26 |
| AXP | -1.69 | -1.13 | -1.12 | -0.41 | 1.67 | -1.33 | 0.15 |
| T | -1.77 | -0.44 | -0.53 | 1.46 | 0.47 | 0.71 | 1.01 |
| MCD | -1.27 | 0.05 | -0.11 | -1.13 | 0.36 | 0.22 | 0.90 |
| SLB | -0.60 | 0.92 | 0.78 | 0.76 | -0.92 | 3.46 | 0.53 |
| TXN | -2.10 | 0.98 | 0.95 | 1.34 | 1.62 | 1.95 | 2.55 |
| DOW | -1.90 | 0.93 | -0.17 | 2.61 | -0.94 | 1.58 | -0.81 |
| ABT | -0.74 | 0.86 | 0.42 | -0.65 | 1.17 | 1.03 | 1.26 |
| CL | -2.10 | -1.02 | -1.16 | -2.48 | 0.31 | -0.56 | 1.03 |
| BAC | -2.26 | -0.23 | -0.19 | 2.67 | 2.93 | 0.49 | 0.66 |
| UTX | 0.73 | 1.19 | -0.33 | -1.61 | -1.00 | 0.97 | -0.99 |
| EMR | -1.02 | 0.78 | 0.63 | 0.55 | -2.17 | 0.85 | -0.35 |
| MDT | -1.71 | 0.16 | 0.15 | 0.04 | 0.94 | 0.92 | 1.58 |
| UNH | -3.24 | 0.85 | 0.75 | 3.07 | 1.38 | 3.51 | 1.53 |

Note: This table compares RK to ACD-ICV method. The benchmark model is HAR-MEM with RK as the volatility measure. $r_t^2$ is the proxy. Model 1 is HAR-MEM-OJ with RK. Model 2 is HAR-MEM-$r$ with RK. Model 3 is HAR-MEM-$r$-OJ with RK. Model 4 is HAR-MEM with ICV. Model 5 is HAR-MEM-OJ with ICV. Model 6 is HAR-MEM-$r$ with ICV. Model 7 is HAR-MEM-$r$-OJ with ICV.

Table B.7: MW statistics of daily volatility models with and without overnight jumps with QLIKE loss function using RK

| Stock | HAR-OJ | HAR-MEM-OJ | HAR-MEM-r-OJ | W-HAR-OJ | W-HAR-MEM-OJ | W-HAR-MEM-r-OJ |
|---|---|---|---|---|---|---|
| IBM | -2.14 | -1.14 | -0.63 | -3.64 | -1.55 | -0.99 |
| GE | -1.25 | -0.88 | -1.09 | -1.80 | -1.59 | -0.76 |
| MO | -2.31 | 0.11 | -0.71 | -2.77 | -0.16 | -0.48 |
| MRK | 0.04 | -0.99 | 1.18 | -0.11 | -1.17 | 1.53 |
| KO | -2.77 | -6.39 | -2.92 | -2.97 | -2.35 | -2.79 |
| PFE | -1.65 | -1.95 | -2.10 | -1.79 | -1.89 | -2.09 |
| JNJ | -0.39 | -5.13 | -1.20 | -1.73 | -1.67 | -1.55 |
| AIG | -1.75 | 1.11 | -2.24 | -1.88 | -1.11 | 0.37 |
| PG | -0.24 | -2.86 | 0.67 | -0.42 | 0.04 | 0.63 |
| WMT | -1.11 | 1.18 | -1.13 | -2.13 | -0.38 | -0.72 |
| JPM | -3.76 | -2.18 | -2.08 | -5.29 | -2.03 | -2.26 |
| PEP | -3.73 | -6.95 | -1.50 | -4.80 | -1.24 | -1.10 |
| DD | -3.06 | -3.55 | -1.76 | -3.11 | -1.94 | -1.28 |
| DIS | -3.06 | -3.95 | -1.55 | -3.40 | -1.47 | -1.30 |
| HD | -5.71 | 2.17 | -2.77 | -6.31 | -2.34 | -1.73 |
| BA | -1.80 | -2.93 | -1.27 | -2.25 | -0.66 | -1.55 |
| MMM | -2.91 | -2.10 | -2.19 | -2.94 | -2.48 | -2.18 |
| AXP | -1.22 | -0.32 | -0.75 | -1.75 | -0.64 | -0.59 |
| T | -3.04 | 3.50 | -1.78 | -3.41 | -1.53 | -1.66 |
| MCD | -3.39 | -3.07 | -2.73 | -3.35 | -3.05 | -2.58 |
| SLB | -2.05 | -2.11 | -1.70 | -2.02 | -1.67 | -1.05 |
| TXN | -1.25 | -4.01 | -0.81 | -1.83 | 0.23 | -0.32 |
| DOW | -1.60 | -1.24 | -1.43 | -1.64 | -1.19 | -1.37 |
| ABT | -1.70 | -1.52 | -1.14 | -1.69 | -1.76 | -0.91 |
| CL | -2.61 | -3.22 | -2.13 | -2.75 | -2.68 | -1.89 |
| BAC | 1.66 | -2.75 | 0.27 | 1.30 | -0.01 | 0.05 |
| UTX | -1.15 | 0.45 | -1.08 | -1.15 | -1.12 | -1.20 |
| EMR | -2.64 | -1.46 | -2.40 | -2.64 | -2.16 | 1.08 |
| MDT | -4.33 | -1.28 | -1.32 | -5.08 | -0.92 | 0.11 |
| UNH | -3.24 | -3.71 | -1.88 | -3.58 | -2.48 | -1.70 |

Note: This table compares models with overnight jump to models without overnight jump. The benchmark model of each model in the table is the one that keeps other specification same, but without overnight jump term. $r_t^2$ is the proxy.

Table B.8: MW statistics of daily volatility models with and without overnight jumps with MSE loss function using RK

| Stock | HAR-OJ | HAR-MEM-OJ | HAR-MEM-r-OJ | W-HAR-OJ | W-HAR-MEM-OJ | W-HAR-MEM-r-OJ |
|---|---|---|---|---|---|---|
| IBM | 1.04 | -2.15 | 1.59 | 0.65 | 1.70 | 1.58 |
| GE | 0.49 | -1.85 | 1.35 | 0.50 | 0.84 | 1.46 |
| MO | 1.27 | 0.69 | 1.26 | 1.25 | 1.09 | 1.22 |
| MRK | 1.01 | -0.03 | 1.02 | 1.01 | 1.02 | 1.04 |
| KO | -0.53 | -3.27 | 0.61 | -0.36 | -0.12 | 0.84 |
| PFE | -1.18 | -0.93 | -0.33 | -1.17 | -1.14 | -0.95 |
| JNJ | 0.94 | -0.05 | 1.01 | 0.94 | 1.00 | 1.02 |
| AIG | -1.00 | 0.69 | 0.58 | -1.34 | -1.28 | 2.15 |
| PG | 1.00 | 0.99 | 1.00 | 1.00 | 1.01 | 1.00 |
| WMT | 0.64 | -1.29 | 0.83 | 0.56 | 0.08 | 0.77 |
| JPM | -1.17 | -0.33 | -1.14 | -1.17 | -1.06 | -1.13 |
| PEP | 0.64 | -0.40 | 0.91 | 0.52 | 1.01 | 0.97 |
| DD | -1.34 | -0.55 | -0.17 | -1.42 | -0.29 | 0.19 |
| DIS | 0.54 | -1.57 | 1.06 | 0.70 | 0.85 | 1.00 |
| HD | -0.82 | -0.49 | 1.44 | -0.81 | 0.91 | 1.03 |
| BA | 0.84 | -0.27 | 0.92 | 0.83 | 0.96 | 0.90 |
| MMM | -1.69 | -2.08 | 0.64 | -1.64 | -1.49 | 0.24 |
| AXP | -0.27 | -1.69 | 1.70 | 0.21 | 1.56 | 1.22 |
| T | -0.82 | -1.77 | 0.12 | -0.85 | -0.33 | -0.03 |
| MCD | 0.88 | -1.27 | 0.71 | 0.89 | 0.46 | 0.74 |
| SLB | -2.01 | -0.60 | -1.57 | -2.03 | -1.52 | -1.24 |
| TXN | 0.45 | -2.10 | 1.01 | -0.23 | 1.02 | 0.66 |
| DOW | -1.02 | -1.90 | -1.13 | -1.01 | -1.07 | -1.18 |
| ABT | -0.17 | -0.74 | 1.21 | -0.17 | 0.19 | 1.17 |
| CL | 0.31 | -2.10 | 0.81 | 0.28 | -0.11 | 0.78 |
| BAC | 1.11 | -2.26 | 0.43 | 0.84 | 1.69 | 0.23 |
| UTX | -1.00 | 0.73 | -0.99 | -1.00 | -1.02 | -1.02 |
| EMR | -2.30 | -1.02 | -2.32 | -2.29 | -2.13 | -0.86 |
| MDT | 1.36 | -1.71 | 1.32 | 1.21 | 1.79 | 1.66 |

Note: This table compares models with overnight jump to models without overnight jump. The benchmark model of each model in the table is the one that keeps other specification same, but without overnight jump term. $r_t^2$ is the proxy.

Table B.9: MW statistics of daily volatility models with and with out overnight jumps with QLIKE loss function using ICV

| Stock | HAR-OJ | HAR-MEM-OJ | HAR-MEM-r-OJ | W-HAR-OJ | W-HAR-MEM-OJ | W-HAR-MEM-r-OJ |
|---|---|---|---|---|---|---|
| IBM | -0.93 | -1.30 | -2.04 | -1.36 | -1.07 | -2.08 |
| GE | -1.34 | -1.71 | -0.95 | -1.46 | -1.66 | -0.71 |
| MO | -1.26 | -0.86 | -0.14 | -1.28 | -0.96 | -0.16 |
| MRK | 0.40 | -0.27 | -0.94 | 0.39 | 0.46 | -0.67 |
| KO | -2.02 | -1.83 | -3.63 | -2.05 | -2.13 | -3.52 |
| PFE | -1.41 | -1.51 | -2.29 | -1.44 | -1.50 | -2.34 |
| JNJ | -0.71 | -1.47 | -2.30 | -0.80 | -1.50 | -3.00 |
| AIG | -1.21 | -1.48 | -2.64 | -1.28 | -1.51 | -2.86 |
| PG | 0.73 | 0.33 | 0.30 | 0.65 | 0.63 | 0.31 |
| WMT | -0.22 | -0.32 | 0.14 | -0.24 | 0.12 | -0.06 |
| JPM | -2.01 | -2.32 | -2.48 | -2.06 | -2.31 | -2.27 |
| PEP | -1.87 | -2.11 | -2.31 | -2.05 | -2.01 | -2.54 |
| DD | -2.26 | -1.74 | -1.82 | -2.31 | -1.70 | -1.85 |
| DIS | -1.49 | -1.37 | -2.91 | -1.40 | -1.82 | -2.95 |
| HD | -2.87 | -2.16 | -2.64 | -2.94 | -2.06 | -2.47 |
| BA | 0.95 | 0.24 | -3.03 | 0.78 | -0.10 | -2.96 |
| MMM | -2.65 | -2.72 | -2.66 | -2.65 | -2.52 | -2.56 |
| AXP | 0.01 | -0.55 | -0.78 | -0.03 | -1.20 | -1.55 |
| T | -2.31 | -2.71 | -3.05 | -2.38 | -2.51 | -3.32 |
| MCD | -2.77 | -3.00 | -2.69 | -2.71 | -2.91 | -2.64 |
| SLB | -1.93 | -1.83 | -2.03 | -1.90 | -1.68 | -1.33 |
| TXN | 0.58 | -1.52 | -0.92 | -0.69 | -1.31 | -0.94 |
| DOW | -1.17 | -1.32 | -1.64 | -1.18 | -1.31 | -1.71 |
| ABT | -1.26 | -1.29 | -1.69 | -1.27 | -1.25 | -1.63 |
| CL | -2.08 | -1.98 | -2.58 | -2.06 | -2.31 | -2.74 |
| BAC | 0.84 | 0.07 | 0.35 | 1.48 | 0.09 | 0.39 |
| UTX | -1.01 | -1.01 | -1.47 | -1.01 | -1.01 | -1.53 |
| EMR | -2.10 | -1.93 | -3.22 | -2.09 | -1.87 | -3.23 |
| MDT | -1.64 | -1.58 | -2.08 | -1.69 | -1.42 | -0.75 |
| UNH | -1.30 | -2.16 | -4.19 | -1.38 | -2.32 | -4.02 |

Note: This table compares models with overnight jump to models without overnight jump. The benchmark model of each model in the table is the one that keeps other specification same, but without overnight jump term. $r_t^2$ is the proxy.

Table B.10: DMW statistics of daily volatility models with and without overnight jumps with the MSE loss function using ICV

| Stock | HAR-OJ | HAR-MEM-OJ | HAR-MEM-r-OJ | W-HAR-OJ | W-HAR-MEM-OJ | W-HAR-MEM-r-OJ |
|---|---|---|---|---|---|---|
| IBM | 1.26 | 1.06 | 1.43 | 0.55 | 1.18 | 1.31 |
| GE | -1.12 | -0.85 | 1.26 | -1.15 | -0.77 | 1.44 |
| MO | 1.44 | 1.28 | 1.19 | 1.43 | 1.31 | 1.18 |
| MRK | 0.98 | 0.99 | 1.03 | 0.98 | 1.04 | 1.04 |
| KO | -1.47 | 0.20 | 1.46 | -1.42 | -0.57 | 1.49 |
| PFE | -1.12 | -1.12 | 0.33 | -1.11 | -1.10 | 0.19 |
| JNJ | 0.92 | 0.94 | 1.01 | 0.92 | 0.94 | 0.99 |
| AIG | -1.10 | -1.28 | 0.26 | -1.14 | -1.31 | 0.38 |
| PG | 0.99 | 1.00 | 1.01 | 0.99 | 1.00 | 1.01 |
| WMT | 0.97 | 1.20 | 1.67 | 0.97 | 1.28 | 1.53 |
| JPM | -1.16 | -1.20 | -1.11 | -1.18 | -1.19 | -1.09 |
| PEP | 0.38 | 0.52 | 0.87 | 0.36 | 0.48 | 0.77 |
| DD | -1.22 | -0.86 | -0.10 | -1.20 | -0.83 | 0.05 |
| DIS | 0.41 | 0.73 | 1.15 | 0.34 | -0.15 | 1.14 |
| HD | -0.73 | -0.17 | 1.35 | -0.70 | -0.28 | 0.95 |
| BA | 0.70 | 0.71 | 0.85 | 0.68 | 0.71 | 0.84 |
| MMM | -2.00 | -2.21 | 0.69 | -1.99 | -1.80 | 0.58 |
| AXP | -0.24 | -0.26 | 1.48 | -0.24 | -0.38 | 1.44 |
| T | -0.76 | -0.70 | 0.09 | -0.83 | -0.64 | -0.10 |
| MCD | -1.44 | -1.53 | 0.90 | -1.46 | -1.55 | 0.91 |
| SLB | -2.07 | -1.91 | -1.74 | -2.14 | -1.81 | -1.40 |
| TXN | 1.11 | -1.18 | 1.52 | 0.03 | -1.16 | 1.48 |
| DOW | -1.03 | -1.06 | -1.00 | -1.03 | -1.06 | -1.01 |
| ABT | -0.69 | -0.60 | 1.23 | -0.70 | -0.61 | 1.25 |
| CL | -1.72 | -1.12 | 1.11 | -1.72 | -1.93 | 1.11 |
| BAC | 1.49 | 1.51 | 1.30 | 1.16 | 1.77 | 1.10 |
| UTX | -1.00 | -1.01 | -1.01 | -1.01 | -1.01 | -1.01 |
| EMR | -2.11 | -2.03 | -1.67 | -2.11 | -2.05 | -1.76 |
| MDT | -0.47 | -0.44 | 1.63 | -0.56 | -0.17 | 1.40 |
| UNH | -1.54 | -2.11 | -0.17 | -1.56 | -2.27 | -0.54 |

Note: This table compares models with overnight jump to models without overnight jump. The benchmark model of each model in the table is the one that keeps other specification same, but without overnight jump term. $r_t^2$ is the proxy.

Table B.11: DMW statistics of intraday volatility forecasts using the MSE loss function (1-252)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.74 | 1.65 | -0.50 | -0.54 | 1.38 | 0.59 | -0.62 | -0.72 | 0.92 |
| GE | -0.67 | -0.43 | -1.24 | 1.24 | 1.57 | -0.31 | 0.02 | -0.15 | -1.58 |
| MO | -0.67 | -0.88 | 0.86 | 1.52 | 1.62 | -1.15 | 2.34 | 2.73 | 1.66 |
| MRK | 0.70 | 0.95 | -0.13 | -0.32 | 2.47 | -1.47 | 1.54 | 1.86 | -1.19 |
| KO | -0.90 | -0.99 | -2.09 | -1.22 | -0.72 | -1.04 | -1.61 | -1.21 | -1.83 |
| PFE | 0.58 | 1.02 | 1.54 | 0.97 | 3.60 | 4.67 | 1.95 | 1.81 | -0.32 |
| JNJ | 1.31 | 1.53 | 0.00 | 1.00 | 1.59 | 2.43 | 0.79 | 0.97 | -0.89 |
| AIG | 0.30 | 0.15 | -1.59 | -1.36 | -0.19 | -1.60 | 0.08 | 0.95 | -1.44 |
| PG | 0.04 | 0.46 | -0.46 | 1.42 | 3.77 | 2.53 | -1.04 | 0.51 | -0.19 |
| WMT | 0.18 | 0.67 | 0.58 | 0.25 | 3.77 | 2.47 | 0.44 | 1.51 | -0.03 |
| JPM | 2.96 | 2.68 | -0.86 | 1.08 | 1.78 | -0.24 | -0.09 | 1.34 | -0.18 |
| PEP | -0.18 | 0.84 | 0.70 | 1.22 | 3.70 | 2.67 | -0.19 | 0.37 | 0.05 |
| DD | -0.68 | -0.61 | 0.42 | 1.09 | 1.08 | -0.81 | -0.76 | 0.83 | 0.26 |
| DIS | 1.19 | 1.14 | -1.12 | 1.38 | 1.43 | -0.31 | 1.10 | 1.19 | 0.24 |
| HD | -0.78 | -0.83 | -0.95 | -0.15 | 1.33 | -0.24 | -1.31 | -0.10 | -1.24 |
| BA | 0.98 | 0.97 | 1.26 | -0.70 | 0.11 | -1.02 | -0.14 | -0.28 | -1.18 |
| MMM | -1.91 | -1.56 | -2.36 | -0.31 | 0.51 | -1.25 | -0.85 | 0.43 | -1.28 |
| AXP | 0.05 | 0.95 | -1.44 | 0.59 | 2.03 | 0.80 | 0.89 | 1.46 | -0.97 |
| T | 0.19 | 0.65 | -1.65 | 0.12 | 1.46 | 0.68 | -1.02 | 0.27 | -1.66 |
| MCD | 0.53 | 0.75 | -0.80 | 1.16 | 3.18 | 1.43 | 0.17 | 1.34 | 0.65 |
| SLB | -1.51 | -1.03 | -2.05 | -2.09 | -0.49 | -1.57 | -1.73 | -0.53 | -1.55 |
| TXN | -1.58 | -1.17 | -1.68 | -0.88 | 0.37 | -1.05 | -1.23 | -1.20 | -1.22 |
| DOW | 0.83 | 0.79 | -1.78 | -0.58 | -0.35 | -0.82 | -0.27 | 0.76 | -0.13 |
| ABT | 0.86 | 1.40 | 1.07 | -0.44 | 0.83 | 0.87 | -1.08 | 0.01 | 0.04 |
| CL | 0.68 | 0.90 | 0.58 | -0.26 | 0.44 | -0.71 | -0.74 | 1.32 | -0.26 |
| BAC | 1.89 | 1.75 | -1.55 | -1.06 | -0.68 | -1.68 | 0.04 | 0.07 | -1.08 |
| UTX | -1.18 | -1.12 | -1.18 | 1.10 | 1.38 | -0.99 | -0.94 | -0.69 | -1.42 |
| EMR | -1.47 | -1.63 | 2.30 | -1.41 | -1.44 | -1.56 | -0.99 | -0.29 | -2.46 |
| MDT | 0.27 | -0.07 | 1.41 | 1.28 | 1.99 | -0.23 | -1.73 | 0.64 | -1.77 |
| UNH | -0.11 | -0.10 | 1.11 | 0.84 | 2.72 | 0.68 | 1.03 | 3.80 | 2.37 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the first to 252th forecasting day.

Table B.12: DMW statistics of intraday volatility forecasts using the MSE loss function (253-504)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -1.12 | -1.12 | -2.26 | -1.93 | -1.21 | -1.34 | -0.59 | -1.15 | 1.32 |
| GE | -0.67 | -0.30 | 0.05 | -1.29 | -0.29 | -0.79 | -1.24 | -0.82 | 1.70 |
| MO | -0.58 | 0.37 | 0.07 | -0.91 | -0.41 | -0.80 | 0.60 | 1.46 | 0.82 |
| MRK | -1.43 | -0.66 | -2.17 | 1.41 | 2.26 | -0.35 | -1.37 | -1.25 | -1.58 |
| KO | -0.27 | 0.16 | -0.67 | -0.42 | 1.97 | 0.14 | -1.14 | -0.92 | -1.35 |
| PFE | -0.24 | 2.33 | 1.08 | -1.40 | 0.70 | -0.13 | -1.36 | -1.01 | -0.75 |
| JNJ | 0.19 | 1.00 | 0.11 | 0.71 | 1.69 | 2.23 | -1.35 | -1.34 | -1.54 |
| AIG | -1.09 | -1.06 | -1.81 | -1.14 | 1.24 | -1.80 | -1.46 | -1.43 | -2.15 |
| PG | -0.83 | 0.70 | -0.56 | -1.07 | 1.30 | 0.66 | -1.31 | -1.09 | -1.17 |
| WMT | -0.93 | -0.41 | -1.19 | -1.49 | 0.76 | -0.71 | -1.40 | -1.43 | -1.80 |
| JPM | -0.86 | -0.80 | -1.09 | -1.13 | -0.85 | -1.17 | 0.55 | 0.77 | -1.66 |
| PEP | -0.82 | 0.12 | -0.08 | 0.15 | 2.11 | 2.35 | -1.53 | -0.75 | -0.65 |
| DD | -1.29 | -1.19 | -1.56 | -1.43 | -0.25 | -0.90 | -1.55 | -1.29 | -1.60 |
| DIS | -1.58 | -1.48 | -1.05 | -0.71 | 0.11 | 0.53 | -1.69 | 0.30 | 1.18 |
| HD | -1.25 | -1.01 | -0.82 | -1.03 | 0.04 | -0.27 | -1.58 | -1.54 | -1.54 |
| BA | -1.59 | -1.28 | -1.05 | -0.92 | 2.43 | 1.40 | -0.88 | 0.10 | 0.83 |
| MMM | -1.01 | -0.76 | -1.04 | -1.23 | -0.72 | -0.99 | -1.64 | -1.63 | -1.99 |
| AXP | -0.57 | -1.09 | 1.38 | -1.89 | 0.57 | -1.16 | -0.18 | 0.15 | -0.47 |
| T | -1.29 | -0.91 | -1.58 | -1.27 | 0.94 | -0.56 | -0.32 | 0.52 | -0.29 |
| MCD | -1.37 | -1.45 | -1.73 | -1.02 | 0.22 | -0.53 | -0.85 | 0.32 | 0.02 |
| SLB | -1.46 | -1.39 | -1.68 | -1.55 | 1.09 | -0.19 | -0.69 | 1.04 | 0.40 |
| TXN | -1.89 | -1.59 | -3.16 | -1.98 | 0.29 | -0.88 | -1.41 | -0.38 | -0.74 |
| DOW | -1.55 | -1.56 | -2.34 | 0.66 | 1.90 | 0.14 | -1.61 | -1.38 | -1.57 |
| ABT | -1.62 | -1.54 | -2.25 | -0.45 | 1.56 | 0.45 | -1.81 | -1.59 | -1.81 |
| CL | -1.33 | -0.63 | -2.14 | -0.46 | 1.38 | -1.26 | -1.62 | -1.33 | -1.60 |
| BAC | -1.11 | -1.02 | -1.36 | -1.39 | -0.77 | -0.77 | -0.47 | -0.37 | -1.39 |
| UTX | -2.10 | -2.10 | -2.61 | -1.82 | -0.45 | -1.36 | -1.53 | -1.62 | 0.19 |
| EMR | -1.48 | -1.64 | 3.08 | -0.98 | -0.51 | -0.84 | -1.39 | -1.25 | -1.75 |
| MDT | -0.57 | -0.04 | -0.63 | -1.31 | 1.63 | -0.73 | -1.15 | -0.72 | -1.18 |
| UNH | -2.18 | -1.91 | -2.14 | -0.89 | 1.44 | -0.24 | -1.21 | -0.58 | -1.44 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 253th to 504th forecasting day.

Table B.13: DMW statistics of intraday volatility forecasts using the MSE loss function (504-756)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 2.10 | 2.92 | 1.39 | -0.40 | 3.07 | 2.93 | 0.49 | -0.39 | -1.18 |
| GE | 0.03 | 2.95 | 3.14 | -1.37 | 1.87 | 3.39 | 0.54 | 1.05 | 0.74 |
| MO | 1.49 | 1.61 | -0.77 | 0.31 | 1.22 | 0.60 | 1.89 | 2.23 | 0.77 |
| MRK | -0.10 | -0.11 | -0.81 | 1.75 | 1.97 | 0.72 | -0.35 | 2.07 | 1.77 |
| KO | 1.30 | 3.33 | 1.53 | -0.68 | 1.53 | 1.15 | 1.54 | 3.73 | 3.55 |
| PFE | 0.97 | 1.90 | 1.09 | 0.64 | 3.86 | 3.16 | 1.01 | 3.01 | 2.78 |
| JNJ | 0.15 | 0.70 | 0.02 | 1.10 | 3.37 | 2.77 | 3.17 | 4.78 | 2.95 |
| AIG | 1.42 | 2.03 | 1.76 | -0.05 | 2.31 | 1.82 | 0.26 | 1.19 | 1.67 |
| PG | -0.30 | 1.75 | 1.45 | 1.76 | 4.72 | 4.10 | -1.00 | 1.33 | 1.80 |
| WMT | 0.75 | 2.05 | 0.96 | 0.13 | 3.06 | 2.11 | -0.24 | -0.30 | -1.29 |
| JPM | -2.49 | -1.60 | -0.53 | 0.09 | 2.70 | 3.51 | -1.04 | 0.54 | 2.26 |
| PEP | -1.87 | 1.43 | 2.99 | 0.16 | 2.77 | 3.00 | -1.79 | 3.92 | 3.77 |
| DD | -0.91 | 0.65 | 1.80 | -0.89 | 3.89 | 3.97 | -0.24 | 2.75 | 2.39 |
| DIS | -1.13 | 0.32 | 3.44 | -1.27 | 2.12 | 3.78 | -0.46 | 3.12 | 4.90 |
| HD | 1.84 | 1.61 | -0.24 | 0.22 | 1.36 | 1.02 | -0.13 | 0.29 | 0.17 |
| BA | 1.19 | 0.50 | -0.59 | -0.97 | 5.34 | 5.53 | -0.24 | 3.76 | 4.14 |
| MMM | 0.49 | 1.18 | -0.14 | -1.39 | 2.58 | 1.96 | 0.96 | 0.71 | -1.01 |
| AXP | -0.97 | -0.77 | 0.55 | -0.58 | 1.75 | 2.09 | 0.65 | 1.29 | 0.99 |
| T | 0.71 | 0.38 | 0.00 | 0.63 | 1.02 | 0.59 | 0.61 | 1.85 | 1.67 |
| MCD | 0.65 | 0.89 | -0.22 | 2.15 | 1.90 | 0.08 | 1.38 | 1.95 | -0.51 |
| SLB | -0.05 | -0.73 | -1.64 | -0.67 | 5.61 | 5.33 | -2.04 | 3.69 | 3.70 |
| TXN | -0.29 | -0.03 | 0.30 | -0.68 | 2.00 | 2.72 | -1.38 | 2.80 | 2.77 |
| DOW | -1.46 | -1.53 | -0.63 | 0.55 | 2.45 | 2.79 | -1.56 | 1.14 | 2.48 |
| ABT | 1.89 | 0.80 | -0.69 | 0.65 | 3.45 | 2.58 | 0.93 | 3.72 | 3.17 |
| CL | -0.37 | -0.83 | -1.58 | 0.00 | 4.83 | 3.72 | 2.37 | 2.98 | 0.91 |
| BAC | -0.66 | -0.24 | 1.13 | -1.44 | 2.64 | 3.30 | 0.99 | 0.82 | -0.33 |
| UTX | -0.68 | -0.74 | -0.76 | 0.25 | 2.34 | 1.61 | 1.09 | 2.70 | 2.29 |
| EMR | 1.16 | 0.67 | -0.39 | -0.83 | 2.60 | 2.92 | 0.22 | 1.70 | 2.15 |
| MDT | -0.11 | 0.87 | 0.61 | 1.30 | 2.37 | 1.31 | 0.69 | 3.42 | 2.61 |
| UNH | 0.38 | 1.11 | -0.79 | -0.23 | 3.39 | 0.81 | 0.90 | 3.20 | 1.02 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 505th to 756th forecasting day.

Table B.14: DMW statistics of intraday volatility forecasts using the MSE loss function (757-1008)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 3.11 | 4.48 | 3.69 | 1.70 | 2.95 | 2.69 | 2.08 | 2.16 | 0.31 |
| GE | 2.67 | 4.12 | 1.94 | 0.92 | 3.54 | 2.28 | 0.77 | 0.63 | -1.25 |
| MO | 0.85 | 1.03 | -1.55 | -0.78 | -0.72 | -1.48 | 1.05 | 1.80 | -1.50 |
| MRK | 0.77 | 0.98 | -0.23 | 0.19 | 1.20 | 0.26 | 1.12 | 1.74 | 0.54 |
| KO | -1.32 | -0.60 | -0.79 | -0.62 | 0.65 | 3.12 | 0.43 | 1.27 | 0.56 |
| PFE | 1.09 | 1.21 | -1.09 | -0.97 | -0.62 | 0.06 | 1.26 | 1.37 | -1.32 |
| JNJ | 0.69 | 1.60 | -0.07 | 1.47 | 2.38 | 1.09 | 2.62 | 3.78 | 1.48 |
| AIG | -1.59 | -0.81 | -1.21 | 1.17 | 1.68 | -0.68 | 1.19 | 1.38 | 0.60 |
| PG | 0.65 | 0.95 | 1.02 | 0.67 | 0.99 | 1.02 | 0.64 | 0.92 | 1.02 |
| WMT | -0.12 | 0.56 | -0.29 | 1.56 | 2.97 | 1.55 | 2.63 | 3.77 | 1.99 |
| JPM | -0.36 | 1.11 | -0.47 | -0.49 | 0.85 | 0.04 | 0.50 | 0.86 | -0.54 |
| PEP | -0.86 | 1.58 | 0.65 | -1.08 | 0.79 | 0.13 | 1.99 | 4.47 | 2.76 |
| DD | -0.32 | 0.11 | 0.09 | 2.00 | 3.82 | 2.48 | 0.31 | 2.73 | 3.09 |
| DIS | -0.15 | 1.53 | 2.00 | -1.28 | 2.52 | 3.46 | 0.90 | -0.65 | -0.58 |
| HD | 0.29 | 0.70 | 0.28 | -0.33 | 2.76 | 1.47 | 2.38 | 3.48 | 1.88 |
| BA | 1.94 | 2.01 | -0.74 | 0.07 | 1.83 | 1.46 | 0.84 | 1.41 | 0.13 |
| MMM | -0.92 | 0.41 | -0.82 | 0.07 | 0.94 | -0.94 | 0.29 | 0.37 | -1.45 |
| AXP | 1.13 | 1.03 | -1.44 | 1.02 | 0.74 | -1.20 | 1.28 | 1.15 | -0.46 |
| T | -0.31 | 0.20 | -0.58 | -0.04 | 2.01 | 1.39 | 1.44 | 2.21 | 0.76 |
| MCD | 0.33 | 1.46 | 1.54 | 2.48 | 4.07 | 2.69 | 2.12 | 4.77 | 1.91 |
| SLB | 0.77 | 0.92 | -1.62 | -1.38 | 0.79 | -0.97 | 1.07 | 2.51 | 0.71 |
| TXN | -0.57 | 0.16 | -0.71 | 0.57 | 3.17 | 0.88 | 1.34 | 2.90 | 1.62 |
| DOW | 1.70 | 1.52 | -0.21 | -0.94 | -0.36 | -1.54 | 1.26 | 1.57 | -0.59 |
| ABT | -0.38 | 0.42 | 0.19 | -0.46 | 1.08 | -0.03 | -0.64 | 0.81 | 0.40 |
| CL | -0.98 | -0.93 | -2.36 | 0.03 | 1.36 | -0.51 | -0.15 | 1.23 | -0.06 |
| BAC | 1.62 | 1.43 | -0.27 | -0.83 | 1.89 | 2.83 | -1.38 | -1.52 | -1.46 |
| UTX | 1.03 | 1.62 | 0.59 | 0.46 | 1.68 | 0.67 | 0.62 | 1.41 | -0.32 |
| EMR | 0.75 | 1.55 | 0.33 | -0.63 | 1.30 | 0.73 | 1.39 | 1.91 | 0.82 |
| MDT | 1.76 | 1.94 | 1.20 | 0.41 | 1.75 | -0.64 | 1.80 | 3.36 | 0.99 |
| UNH | -1.19 | -1.13 | -2.10 | 0.06 | 1.17 | -1.75 | 1.32 | 1.49 | -1.34 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 757th to 1008th forecasting day.

Table B.15: DMW statistics of intraday volatility forecasts using the MSE loss function (1009-1260)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.13 | 0.82 | -0.60 | -0.87 | -0.04 | -0.76 | 0.44 | 1.62 | 0.52 |
| GE | 1.82 | 3.30 | 1.44 | 1.32 | 3.08 | 1.86 | 1.86 | 2.03 | 0.04 |
| MO | -0.08 | 0.42 | -1.73 | 1.59 | 1.97 | 1.59 | 1.37 | 2.03 | -1.56 |
| MRK | 1.73 | 1.81 | -0.97 | 1.69 | 1.89 | 0.41 | 0.63 | 0.41 | -1.51 |
| KO | 0.11 | 0.51 | 0.99 | 1.00 | 3.03 | 2.91 | -1.36 | 1.81 | 3.70 |
| PFE | -0.34 | 0.89 | 0.55 | 1.77 | 2.41 | 0.86 | 1.48 | 1.70 | -0.18 |
| JNJ | -0.58 | -0.01 | -0.67 | -1.34 | -0.26 | -0.59 | 0.61 | 2.45 | 0.86 |
| AIG | 0.56 | 0.81 | -1.35 | -0.91 | -0.74 | -0.89 | 1.05 | 2.11 | -0.49 |
| PG | -0.21 | 0.09 | -0.78 | 1.60 | 2.29 | -0.04 | -0.94 | -0.43 | -0.92 |
| WMT | 0.07 | 1.01 | -1.15 | -0.55 | 2.30 | -0.62 | -0.08 | 3.00 | 0.46 |
| JPM | -0.65 | 0.00 | -1.22 | -0.55 | 1.23 | -0.34 | 2.16 | 2.34 | 0.32 |
| PEP | 3.62 | 4.15 | 1.73 | 0.64 | 2.26 | 0.81 | 2.59 | 5.14 | 2.75 |
| DD | 1.22 | 1.42 | -1.88 | 0.33 | 0.35 | -1.61 | -1.26 | -0.23 | -1.62 |
| DIS | 2.72 | 2.86 | 1.29 | 0.70 | 1.30 | 0.52 | 2.27 | 3.80 | 1.65 |
| HD | 1.85 | 2.97 | 0.18 | 0.38 | 2.42 | -0.62 | -0.13 | 1.36 | -1.29 |
| BA | 0.09 | 0.02 | -1.80 | 0.77 | 2.52 | 0.28 | 1.08 | 1.51 | -0.33 |
| MMM | -0.95 | -0.48 | -1.52 | 1.04 | 1.96 | -0.93 | 0.26 | 1.77 | -0.78 |
| AXP | -0.59 | -0.26 | -0.69 | -1.66 | -1.45 | -0.31 | -1.27 | -1.23 | -0.26 |
| T | -0.86 | -0.01 | -1.36 | -0.25 | 1.97 | 0.14 | -0.07 | 2.11 | -0.52 |
| MCD | -1.44 | -0.93 | -1.99 | -0.92 | 0.47 | -0.93 | -1.24 | -0.72 | -1.61 |
| SLB | -1.10 | -0.63 | -3.57 | -2.05 | -1.62 | -2.52 | -2.09 | -0.30 | -2.35 |
| TXN | 0.83 | 2.23 | 1.03 | -1.02 | 0.83 | 0.82 | 0.25 | 1.43 | 0.15 |
| DOW | 0.61 | 1.78 | -2.28 | -0.42 | -0.20 | -0.64 | 0.92 | 2.65 | -1.13 |
| ABT | -0.72 | 0.34 | -1.74 | 0.95 | 1.81 | -0.67 | 1.48 | 3.17 | 1.34 |
| CL | 1.23 | 1.31 | -0.80 | 0.70 | 1.60 | -0.16 | -0.52 | 2.87 | 0.16 |
| BAC | 1.46 | 1.86 | 1.31 | -1.10 | 0.11 | -1.23 | 0.46 | 0.65 | -1.07 |
| UTX | 0.32 | 1.66 | 0.52 | -0.41 | 0.88 | -0.19 | 2.69 | 3.03 | 1.46 |
| EMR | -0.09 | 1.13 | -0.45 | -0.53 | 0.40 | -0.95 | 0.69 | 2.00 | -1.08 |
| MDT | 0.62 | 1.59 | -0.79 | 1.37 | 3.70 | 0.90 | 1.99 | 4.05 | 0.98 |
| UNH | -1.10 | -0.65 | -1.93 | -1.20 | 0.19 | -2.07 | 0.78 | 1.87 | -2.02 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 1009th to 1260th forecasting day.

captionDMW statistics of intraday volatility forecasts using the MSE loss function (1261-end)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.22 | 2.65 | 0.90 | 1.41 | 2.61 | 0.01 | 0.04 | 0.83 | -1.34 |
| GE | 1.01 | 1.76 | 1.14 | 1.63 | 2.99 | 2.55 | -1.07 | -0.79 | -1.69 |
| MO | -0.57 | 1.33 | 1.00 | -0.20 | 1.49 | 1.04 | -0.19 | 0.70 | 0.90 |
| MRK | 1.30 | 2.04 | -2.07 | 1.68 | 2.63 | 0.32 | -0.71 | 0.38 | -1.30 |
| KO | 2.09 | 2.28 | 1.67 | -0.25 | 0.61 | -0.05 | -1.28 | 0.13 | -0.47 |
| PFE | 0.72 | 1.46 | 1.97 | 1.33 | 2.66 | 5.32 | 1.94 | 2.29 | 2.02 |
| JNJ | 1.90 | 2.69 | 2.27 | 0.96 | 4.04 | 3.94 | -0.71 | -0.08 | -0.35 |
| AIG | 1.53 | 1.98 | 0.49 | 0.91 | 1.49 | -0.88 | 0.20 | 0.84 | -1.38 |
| PG | 0.57 | 2.38 | 2.02 | 0.16 | 3.83 | 3.98 | 0.09 | 0.09 | -0.90 |
| WMT | 2.02 | 2.87 | 0.85 | 2.51 | 3.91 | 2.42 | 1.03 | 2.36 | 0.84 |
| JPM | 0.67 | 1.26 | 0.24 | 1.18 | 1.62 | 0.29 | -0.23 | 0.49 | -1.70 |
| PEP | 2.35 | 2.71 | 0.67 | 1.57 | 4.18 | 2.85 | -1.82 | -0.37 | -0.91 |
| DD | 2.02 | 2.44 | 1.22 | 0.10 | 1.63 | 0.19 | -0.21 | 1.38 | -0.72 |
| DIS | 0.34 | 0.44 | -1.98 | 0.24 | 1.38 | 0.64 | -0.68 | -0.39 | -1.09 |
| HD | 1.51 | 2.99 | 1.84 | -1.67 | -0.08 | -1.30 | -0.86 | -0.30 | -1.43 |
| BA | -1.08 | -0.58 | -0.59 | -0.37 | 1.15 | -0.11 | -1.80 | -0.99 | -2.18 |
| MMM | 0.67 | 1.57 | 0.18 | 0.10 | 0.30 | -1.41 | 0.76 | 2.21 | -0.69 |
| AXP | 1.72 | 2.06 | 1.56 | 1.14 | 1.35 | 0.04 | -0.63 | -0.78 | -1.02 |
| T | 0.66 | 0.90 | -0.49 | 0.45 | 1.41 | 1.00 | -0.59 | 0.04 | -2.01 |
| MCD | 1.19 | 2.12 | 0.68 | -0.83 | 0.59 | 0.10 | -0.95 | -0.45 | -0.87 |
| SLB | 0.59 | 1.56 | 0.44 | 0.49 | 1.22 | -0.14 | -2.30 | -1.71 | -2.24 |
| TXN | 0.45 | 1.76 | 0.99 | -0.98 | 0.37 | -0.70 | 0.32 | 2.58 | 1.54 |
| DOW | 1.50 | 2.47 | 1.50 | 2.09 | 2.58 | -0.12 | -0.62 | 0.71 | -1.22 |
| ABT | -0.98 | 0.41 | -0.68 | 1.77 | 2.55 | 1.55 | -1.73 | 0.29 | -0.60 |
| CL | 0.57 | 1.51 | -0.40 | 0.07 | 2.68 | 0.90 | -1.49 | 0.05 | -0.82 |
| BAC | 0.07 | 1.24 | 0.31 | 0.88 | 2.34 | 1.09 | -1.06 | -0.66 | -1.10 |
| UTX | 0.07 | 0.34 | -1.14 | -0.76 | 1.23 | 0.82 | -2.10 | -1.43 | -1.61 |
| EMR | -1.39 | -0.32 | -2.21 | -1.16 | 0.54 | -0.21 | -1.49 | -1.24 | -1.78 |
| MDT | 1.05 | 2.01 | -0.80 | 0.78 | 3.39 | 1.03 | 0.48 | 3.24 | -0.14 |
| UNH | -1.62 | -0.55 | -2.48 | -0.91 | 0.25 | -1.26 | -0.06 | 2.12 | -0.32 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 1261th to the end of forecasting days.

Table B.16: DMW statistics of intraday volatility forecasts using the MSE loss function (whole period)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.20 | 1.26 | -0.89 | -1.85 | -0.42 | -0.87 | -0.80 | -1.03 | 1.41 |
| GE | -0.85 | -0.32 | -0.90 | -0.70 | 0.56 | -0.62 | -1.06 | -0.76 | -0.30 |
| MO | 0.13 | 2.20 | 0.75 | -0.38 | 1.17 | 0.22 | 1.54 | 3.26 | 1.28 |
| MRK | 0.11 | 1.12 | -2.24 | 1.89 | 3.43 | -0.29 | -1.04 | -0.79 | -1.99 |
| KO | -0.59 | -0.09 | -1.50 | -1.33 | 1.01 | -0.45 | -1.43 | -1.12 | -1.83 |
| PFE | 1.11 | 2.14 | 0.05 | -1.33 | 1.21 | 0.91 | 0.15 | 0.41 | -0.91 |
| JNJ | 0.87 | 1.37 | 0.17 | 1.21 | 2.08 | 2.98 | -1.16 | -0.95 | -1.46 |
| AIG | -0.97 | -0.86 | -2.27 | -1.33 | 1.16 | -1.98 | -1.28 | -0.88 | -2.38 |
| PG | 0.63 | 0.96 | 0.99 | 0.64 | 1.03 | 1.04 | 0.55 | 0.87 | 0.97 |
| WMT | -0.79 | 0.03 | -0.96 | -1.20 | 1.69 | -0.04 | -1.33 | -1.22 | -1.38 |
| JPM | -0.73 | -0.66 | -1.14 | -1.05 | -0.63 | -1.09 | 0.53 | 0.90 | -1.67 |
| PEP | -0.83 | 0.52 | 0.58 | 0.78 | 2.60 | 3.11 | -1.56 | -0.44 | -0.20 |
| DD | -1.24 | -1.06 | -1.35 | -1.02 | 0.42 | -0.69 | -1.61 | -0.90 | -1.22 |
| DIS | 0.41 | 0.42 | -0.83 | 0.42 | 1.38 | 1.05 | 0.78 | 1.26 | 2.09 |
| HD | -1.28 | -0.90 | -0.73 | -1.04 | 0.59 | -0.27 | -1.79 | -1.31 | -1.80 |
| BA | 0.63 | 0.46 | -0.65 | -1.08 | 2.40 | 1.83 | -0.56 | -0.04 | -0.26 |
| MMM | -2.09 | -1.54 | -2.44 | -1.14 | -0.05 | -1.53 | -1.72 | -0.77 | -2.30 |
| AXP | -0.25 | 0.42 | 0.60 | -0.72 | 1.92 | -0.63 | 0.25 | 1.23 | -1.01 |
| T | -1.21 | -0.82 | -1.65 | -1.01 | 1.30 | -0.39 | -0.47 | 0.73 | -0.33 |
| MCD | -1.22 | -1.22 | -1.76 | -0.15 | 1.47 | -0.17 | -0.24 | 1.30 | 0.11 |
| SLB | -1.88 | -1.31 | -2.54 | -2.46 | 0.38 | -1.24 | -2.83 | -0.21 | -1.61 |
| TXN | -2.07 | -1.55 | -2.65 | -1.56 | 0.63 | -1.06 | -1.57 | -1.03 | -0.75 |
| DOW | -0.26 | -0.29 | -2.60 | -0.39 | 0.45 | -0.63 | -1.53 | -0.74 | -1.39 |
| ABT | -1.50 | -1.31 | -2.04 | -0.29 | 2.07 | 1.25 | -1.80 | -1.21 | -1.17 |
| CL | -0.81 | -0.49 | -1.63 | -0.46 | 2.08 | -0.78 | -1.60 | -0.78 | -1.52 |
| BAC | -0.35 | -0.41 | -1.39 | -1.64 | -0.71 | -1.44 | -0.86 | -0.41 | -1.48 |
| UTX | -1.95 | -1.90 | -2.37 | 0.98 | 1.30 | -1.06 | -1.35 | -1.00 | -1.39 |
| EMR | -2.03 | -2.11 | 2.93 | -1.48 | -0.72 | -0.81 | -1.61 | -1.35 | -2.74 |
| MDT | -0.09 | 0.34 | 0.91 | 0.19 | 2.80 | -0.48 | -1.29 | -0.27 | -1.52 |
| UNH | -2.55 | -2.12 | -3.11 | -1.03 | 2.67 | -0.46 | -0.47 | 1.36 | -0.92 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period includes whole forecasting days.

Table B.17: DMW statistics of intraday volatility forecasts using the QLIKE loss function (1-252)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.56 | 0.89 | -0.62 | -0.98 | 1.22 | 0.90 | -0.92 | -0.67 | 1.46 |
| GE | -1.37 | -1.82 | -2.81 | -0.51 | -0.88 | -1.83 | -1.07 | -1.29 | -1.78 |
| MO | -0.59 | -0.62 | 0.90 | 1.72 | 1.68 | -0.73 | 2.39 | 2.27 | 0.88 |
| MRK | -0.23 | 0.17 | -0.11 | -0.77 | -0.31 | -2.07 | -1.16 | -1.00 | -1.27 |
| KO | -2.00 | -1.99 | -2.79 | -1.21 | -0.51 | -0.97 | -2.53 | -1.79 | -1.99 |
| PFE | 0.15 | 1.25 | 1.65 | -0.56 | 3.16 | 3.02 | 2.61 | 1.20 | -0.98 |
| JNJ | 0.38 | 1.21 | 0.32 | 1.20 | 3.54 | 2.05 | -0.49 | -0.05 | -0.89 |
| AIG | -1.15 | -1.16 | -2.16 | -1.47 | -1.10 | -1.56 | -2.41 | -1.74 | -2.74 |
| PG | -0.95 | 0.08 | 0.18 | 0.65 | 2.73 | 2.35 | -0.66 | 0.85 | 0.56 |
| WMT | 0.21 | 1.27 | 1.27 | 1.60 | 4.66 | 3.80 | -0.31 | 0.18 | -0.44 |
| JPM | 0.97 | -0.62 | -1.51 | -0.43 | 0.60 | 0.01 | -0.88 | -0.15 | -0.39 |
| PEP | 0.89 | 2.17 | 1.87 | 1.29 | 4.17 | 1.99 | -0.16 | 0.25 | 0.13 |
| DD | -0.70 | -0.37 | 0.63 | 0.15 | -0.04 | -1.06 | -0.65 | 0.44 | -0.23 |
| DIS | 0.35 | -0.21 | -1.08 | 0.75 | 0.58 | -0.15 | -0.19 | 0.45 | 0.03 |
| HD | -0.86 | -0.30 | -1.43 | -0.86 | -0.30 | -1.43 | -0.86 | -0.30 | -1.43 |
| BA | 0.27 | 0.37 | 1.27 | -1.49 | -0.81 | -1.32 | -0.64 | -0.79 | -1.60 |
| MMM | -2.49 | -2.17 | -2.65 | -1.66 | -1.17 | -1.48 | -2.09 | -1.42 | -2.22 |
| AXP | -2.08 | -2.01 | -2.81 | -0.57 | 0.96 | 0.43 | -0.99 | -1.30 | -2.16 |
| T | -1.52 | -0.92 | -1.97 | 0.16 | 1.77 | 0.85 | -1.52 | -0.73 | -1.98 |
| MCD | -0.09 | -0.74 | -1.25 | 0.75 | 1.31 | 0.60 | -0.44 | -0.09 | -0.13 |
| SLB | -1.96 | -1.67 | -2.44 | -2.44 | -1.39 | -1.92 | -1.72 | -1.14 | -1.57 |
| TXN | -1.96 | -1.56 | -1.78 | -1.05 | -0.02 | -0.79 | -1.85 | -1.76 | -1.57 |
| DOW | 0.46 | 0.38 | -1.50 | -0.97 | -0.88 | -0.97 | -1.45 | -1.03 | -1.15 |
| ABT | 0.40 | 0.49 | -0.22 | -1.29 | 1.49 | 1.74 | -1.66 | -0.55 | -0.54 |
| CL | 1.05 | 1.22 | 0.85 | -1.14 | -0.11 | -0.84 | -1.89 | 0.18 | -0.62 |
| BAC | 0.29 | 0.06 | -0.54 | -0.88 | -1.19 | -1.78 | -0.92 | -1.04 | -1.68 |
| UTX | -1.70 | -1.67 | -1.94 | 1.06 | 1.36 | -0.87 | -1.62 | -1.49 | -2.13 |
| EMR | -2.19 | -1.94 | 3.07 | -2.69 | -2.71 | -2.25 | -1.84 | -1.46 | -2.58 |
| MDT | -1.25 | -1.56 | 1.69 | -0.30 | 0.64 | -0.27 | -3.08 | -1.49 | -2.72 |
| UNH | -0.01 | 0.06 | 0.92 | 0.05 | 1.82 | 0.57 | 0.58 | 2.92 | 1.78 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from first to 252 forecasting day.

Table B.18: DMW statistics of intraday volatility forecasts using the QLIKE loss function (253-504)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -1.95 | -1.85 | -2.14 | -1.66 | -0.70 | -0.90 | -1.45 | -1.81 | 1.73 |
| GE | -1.02 | -0.54 | -0.28 | -1.88 | -0.97 | -0.94 | -1.87 | -1.00 | 1.69 |
| MO | -0.11 | -0.23 | -1.26 | -1.18 | -0.87 | -0.93 | -1.41 | -0.27 | -0.38 |
| MRK | -3.04 | -2.75 | -3.51 | -1.70 | -0.32 | -1.21 | -1.79 | -1.51 | -1.77 |
| KO | -0.93 | -0.65 | -1.28 | -1.44 | 0.53 | -0.40 | -1.46 | -0.94 | -1.24 |
| PFE | -0.82 | 1.21 | 0.94 | -1.39 | 0.01 | -0.09 | -1.55 | -0.62 | -0.01 |
| JNJ | -1.56 | -1.19 | -1.80 | -0.73 | 1.42 | 0.83 | -1.65 | -1.64 | -1.94 |
| AIG | -2.20 | -2.18 | -3.00 | -1.56 | -0.40 | -2.07 | -2.53 | -2.39 | -3.45 |
| PG | -0.99 | 0.36 | -0.14 | -1.38 | 0.92 | 0.45 | -1.66 | -1.18 | -1.31 |
| WMT | -1.43 | -0.36 | -1.36 | -1.61 | 0.29 | -0.49 | -1.72 | -1.80 | -2.39 |
| JPM | -1.48 | -1.43 | -1.22 | -1.53 | -0.93 | -0.92 | -1.34 | -1.19 | -1.64 |
| PEP | -1.13 | -0.48 | -0.40 | -1.13 | 1.37 | 1.20 | -1.23 | -0.63 | -0.53 |
| DD | -1.99 | -1.67 | -2.10 | -1.49 | -0.03 | -0.50 | -1.65 | -1.30 | -1.54 |
| DIS | -1.45 | -1.54 | -0.51 | -0.60 | -0.51 | -0.02 | -1.81 | 0.28 | 1.41 |
| HD | -0.86 | -0.30 | -1.43 | -0.86 | -0.30 | -1.43 | -0.86 | -0.30 | -1.43 |
| BA | -2.29 | -1.51 | -0.92 | -2.11 | -0.36 | -0.31 | -1.12 | 0.79 | 1.43 |
| MMM | -1.37 | -0.81 | -1.27 | -1.20 | 0.13 | -0.31 | -2.23 | -2.06 | -2.17 |
| AXP | -1.85 | -2.35 | 1.69 | -2.37 | -0.03 | -0.61 | -1.33 | -0.86 | -0.14 |
| T | -2.17 | -1.74 | -2.45 | -1.92 | -1.20 | -1.60 | -1.51 | -1.07 | -1.38 |
| MCD | -2.47 | -2.45 | -2.22 | -0.48 | -0.23 | -0.71 | -1.05 | -0.13 | -0.48 |
| SLB | -1.76 | -1.49 | -1.52 | -1.24 | 0.43 | -0.21 | -1.36 | 0.57 | 0.31 |
| TXN | -2.52 | -2.65 | -3.46 | -2.12 | -0.41 | -0.72 | -1.40 | -0.17 | -0.23 |
| DOW | -1.82 | -1.84 | -2.80 | -1.23 | 0.50 | -0.50 | -2.06 | -1.89 | -2.20 |
| ABT | -1.86 | -1.83 | -2.81 | -1.81 | -0.36 | -1.28 | -2.44 | -1.67 | -1.88 |
| CL | -2.63 | -2.48 | -3.22 | -0.75 | 0.41 | -1.46 | -1.54 | -1.21 | -1.56 |
| BAC | -1.68 | -1.26 | -1.39 | -1.30 | 0.06 | 0.04 | -1.38 | -1.33 | -1.16 |
| UTX | -2.81 | -2.83 | -3.59 | -2.13 | -0.66 | -1.41 | -2.41 | -2.31 | -1.17 |
| EMR | -2.56 | -2.45 | 3.52 | -1.02 | -0.04 | -0.01 | -1.40 | -1.11 | -1.65 |
| MDT | -0.96 | -0.53 | -0.90 | -1.53 | 1.05 | -0.39 | -1.27 | -0.42 | -0.95 |
| UNH | -2.43 | -2.24 | -2.73 | -1.38 | 0.47 | -0.69 | -1.68 | -1.10 | -1.54 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 253th to 504th forecasting day.

Table B.19: DMW statistics of intraday volatility forecasts using QLIKE loss function (505-756)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.88 | 2.62 | 1.27 | 0.03 | 3.99 | 4.04 | 0.26 | -0.50 | -0.82 |
| GE | -0.43 | 1.13 | 1.48 | -1.72 | 1.02 | 1.55 | 0.05 | -0.60 | -0.53 |
| MO | -0.15 | -0.29 | -0.72 | -1.67 | -0.53 | -0.97 | 1.23 | 2.21 | 1.34 |
| MRK | -0.29 | -0.43 | -0.92 | 0.99 | 0.78 | 0.00 | -0.59 | 1.84 | 1.53 |
| KO | 0.67 | 2.42 | 1.86 | -0.58 | 0.61 | 0.36 | 0.19 | 1.61 | 1.38 |
| PFE | -1.09 | -0.65 | -0.62 | -0.28 | 3.02 | 2.86 | 0.32 | 2.19 | 1.97 |
| JNJ | 0.06 | 0.13 | -0.44 | 0.99 | 1.79 | 1.18 | 2.29 | 3.22 | 2.31 |
| AIG | -0.21 | 0.47 | 0.17 | -0.10 | 1.62 | 1.09 | 0.02 | 1.20 | 0.79 |
| PG | -1.02 | 2.47 | 2.37 | 0.31 | 5.25 | 5.01 | -0.62 | 0.84 | 0.91 |
| WMT | -0.14 | 0.95 | -0.04 | -0.42 | 1.86 | 1.13 | -0.29 | -0.27 | -1.22 |
| JPM | -2.95 | -1.28 | 0.23 | 0.53 | 4.09 | 4.77 | -0.75 | -0.37 | 1.14 |
| PEP | -2.09 | 1.22 | 2.89 | 0.21 | 1.33 | 2.45 | -0.73 | 3.37 | 4.16 |
| DD | -0.50 | 0.25 | 0.56 | -0.13 | 2.89 | 2.89 | -0.71 | 0.68 | 0.92 |
| DIS | -0.76 | 0.57 | 4.63 | -1.45 | 1.34 | 3.68 | -1.72 | 5.31 | 8.99 |
| HD | -0.86 | -0.30 | -1.43 | -0.86 | -0.30 | -1.43 | -0.86 | -0.30 | -1.43 |
| BA | 1.34 | 0.35 | -1.05 | -0.45 | 3.71 | 4.64 | -1.18 | 4.40 | 5.45 |
| MMM | -0.46 | 0.07 | -0.45 | -1.77 | 0.77 | 0.17 | 0.03 | -0.03 | -0.97 |
| AXP | 0.33 | 0.47 | 0.46 | -0.59 | 0.89 | 1.10 | -0.43 | -0.56 | -0.37 |
| T | 0.35 | -0.16 | -0.58 | -0.32 | 0.06 | 0.21 | 2.46 | 0.03 | -0.27 |
| MCD | 0.24 | 0.10 | -0.82 | 0.95 | -0.54 | -0.70 | 1.30 | 1.58 | -0.17 |
| SLB | 0.11 | -1.12 | -2.30 | -0.81 | 5.33 | 5.44 | -1.03 | 2.92 | 3.00 |
| TXN | -0.03 | -0.15 | -0.79 | -0.80 | 0.80 | 0.96 | -1.70 | 0.54 | 0.76 |
| DOW | -0.75 | -1.15 | -1.09 | -0.07 | 2.09 | 2.30 | -1.80 | -0.02 | 0.63 |
| ABT | 1.80 | 0.77 | -0.49 | -0.20 | 1.95 | 1.63 | 0.42 | 3.15 | 2.60 |
| CL | 0.25 | -0.43 | -1.30 | -0.87 | 2.84 | 1.83 | 1.80 | 1.78 | 0.08 |
| BAC | 0.35 | 1.55 | 2.54 | -1.39 | 2.86 | 2.91 | 0.51 | -0.28 | -0.78 |
| UTX | -0.34 | -0.29 | -0.59 | -0.86 | 1.22 | 1.27 | -0.56 | 0.95 | 1.09 |
| EMR | -0.80 | -0.60 | -0.72 | -0.12 | 1.04 | 0.99 | 0.63 | 1.16 | 1.29 |
| MDT | -0.17 | 0.02 | -0.82 | 0.80 | 1.81 | 0.61 | -0.07 | 2.00 | 1.33 |
| UNH | -0.30 | 0.23 | -0.41 | -1.22 | 1.16 | -0.05 | 0.07 | 1.86 | 0.77 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 505th to 756th forecasting day.

Table B.20: DMW statistics of intraday volatility forecasts using the QLIKE loss function (757-1008)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 3.65 | 3.38 | 1.96 | 1.82 | 2.69 | 2.03 | 1.83 | 1.90 | 1.11 |
| GE | 1.51 | 2.50 | 0.62 | -0.45 | 1.69 | 0.87 | 0.03 | -0.07 | -1.34 |
| MO | -1.22 | -1.04 | -1.79 | -1.31 | -1.26 | -1.46 | -2.06 | -1.01 | -1.92 |
| MRK | -1.43 | -1.32 | -1.46 | -1.34 | -1.18 | -2.23 | -1.08 | -0.93 | -1.84 |
| KO | -0.88 | -0.55 | -0.98 | 0.01 | 2.07 | 1.75 | -0.24 | 0.60 | -0.09 |
| PFE | 0.86 | 0.92 | -1.06 | -2.21 | -1.35 | -1.65 | 0.15 | -0.33 | -1.42 |
| JNJ | -0.87 | 0.26 | -0.71 | 0.42 | 1.36 | 0.54 | 1.07 | 1.86 | 0.54 |
| AIG | -1.56 | -1.01 | -1.14 | -0.45 | -0.52 | -0.82 | 0.68 | 1.16 | -0.11 |
| PG | -2.71 | -1.20 | -1.74 | -1.39 | 0.35 | -0.79 | -0.45 | 0.15 | -0.75 |
| WMT | -0.41 | 0.24 | -0.84 | 0.68 | 1.69 | 0.18 | 1.64 | 2.53 | 1.33 |
| JPM | -1.59 | -0.08 | -0.36 | 0.13 | 0.55 | -0.29 | -0.74 | -0.46 | -0.98 |
| PEP | -1.68 | 0.22 | -0.34 | -1.31 | 0.03 | -0.47 | 1.64 | 3.79 | 2.61 |
| DD | -0.38 | 0.17 | 0.25 | 1.58 | 1.94 | 0.91 | -0.70 | 1.62 | 1.81 |
| DIS | -0.87 | 0.38 | 1.18 | -0.51 | 1.45 | 2.28 | 1.20 | -1.24 | -0.94 |
| HD | -0.86 | -0.30 | -1.43 | -0.52 | 1.98 | 0.75 | 1.50 | 2.45 | 1.45 |
| BA | 0.91 | 0.83 | -0.96 | -0.51 | 0.47 | 0.08 | -0.44 | -0.45 | -1.02 |
| MMM | -1.41 | -0.47 | -1.27 | -0.89 | -0.16 | -1.35 | -0.10 | -0.11 | -1.56 |
| AXP | -0.42 | -0.49 | -1.43 | -0.45 | -0.89 | -1.52 | 0.49 | 0.44 | -0.03 |
| T | -0.90 | -0.38 | -1.08 | -1.14 | 0.36 | -0.03 | 0.57 | 1.03 | 0.14 |
| MCD | 0.08 | 1.03 | 0.73 | 3.18 | 3.08 | 1.73 | 1.57 | 2.70 | 1.62 |
| SLB | -0.40 | -0.36 | -2.39 | -2.23 | -0.73 | -1.86 | -0.23 | 0.92 | -0.16 |
| TXN | -1.21 | -0.58 | -1.13 | -0.30 | 1.56 | 0.15 | 0.75 | 2.16 | 1.16 |
| DOW | 0.78 | 0.54 | -0.10 | -1.36 | -1.15 | -2.09 | 0.10 | 0.37 | -0.98 |
| ABT | -0.44 | 0.35 | -0.25 | -1.08 | 0.01 | -0.65 | -1.00 | 0.13 | -0.35 |
| CL | -1.48 | -1.50 | -2.68 | -0.65 | -0.08 | -1.57 | -0.31 | 0.85 | -0.30 |
| BAC | 0.66 | -0.08 | -0.54 | -0.78 | 2.07 | 2.20 | -2.00 | -1.96 | -1.11 |
| UTX | 0.14 | 0.62 | -0.24 | -0.28 | 0.50 | -0.13 | 0.10 | 0.79 | -0.25 |
| EMR | 0.14 | 1.13 | -0.06 | -1.41 | 0.75 | 0.19 | 0.55 | 1.32 | 1.18 |
| MDT | 1.09 | 1.38 | 0.83 | -1.20 | -0.30 | -1.38 | 0.44 | 1.84 | 0.19 |
| UNH | -1.99 | -1.74 | -2.56 | -1.93 | -0.52 | -1.72 | -0.48 | 0.02 | -1.40 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 757th to 1008th forecasting day.

Table B.21: DMW statistics of intraday volatility forecasts using the QLIKE loss function (1009-1260)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -0.10 | 0.33 | -0.62 | -1.35 | -0.73 | -1.14 | 0.10 | 1.08 | 0.32 |
| GE | 0.88 | 1.63 | 0.29 | -0.02 | 1.08 | 0.38 | 1.73 | 1.55 | -0.16 |
| MO | -1.81 | -1.66 | -2.02 | 1.35 | 3.14 | 0.19 | -0.09 | 0.52 | -1.68 |
| MRK | -0.27 | 0.18 | -1.27 | 0.22 | 1.43 | -0.51 | -0.73 | -1.26 | -1.35 |
| KO | 0.58 | 0.83 | 0.99 | 0.77 | 2.43 | 2.01 | -0.83 | 3.00 | 3.57 |
| PFE | -0.33 | 0.74 | 0.42 | 0.24 | 1.02 | 0.46 | -0.11 | -0.22 | -0.91 |
| JNJ | -1.00 | -0.07 | -0.45 | -1.63 | 0.00 | -0.36 | 0.35 | 2.30 | 0.81 |
| AIG | -1.10 | -0.74 | -1.62 | -0.94 | -0.45 | -0.92 | 0.16 | 2.62 | 0.27 |
| PG | 0.08 | 0.20 | -0.81 | -0.50 | 0.14 | -0.89 | -1.46 | -0.60 | -0.89 |
| WMT | -0.52 | -0.03 | -1.44 | -1.94 | -0.07 | -1.34 | -0.87 | 0.95 | -0.31 |
| JPM | -0.81 | -0.53 | -1.54 | -0.98 | 0.32 | -0.85 | 2.03 | 2.18 | 0.26 |
| PEP | 2.83 | 2.40 | 0.67 | -0.30 | 0.99 | 0.22 | 0.80 | 1.81 | 0.66 |
| DD | -0.18 | 0.02 | -2.50 | -0.79 | -0.75 | -1.98 | -1.81 | -1.28 | -2.05 |
| DIS | 2.72 | 2.53 | 0.77 | 0.07 | 0.14 | -0.20 | 1.57 | 3.13 | 0.94 |
| HD | 1.08 | 1.89 | -0.25 | -1.42 | -0.18 | -1.56 | -1.21 | -0.42 | -1.89 |
| BA | -0.96 | -1.06 | -2.25 | -0.63 | 0.96 | -0.60 | 0.13 | 0.61 | -0.37 |
| MMM | -1.43 | -0.95 | -2.03 | -0.29 | 0.47 | -1.33 | 0.62 | 0.95 | -0.98 |
| AXP | -1.51 | -1.41 | -2.09 | -2.78 | -2.45 | -3.67 | -2.10 | -2.11 | -2.98 |
| T | -0.94 | -0.35 | -2.04 | -1.82 | -0.57 | -1.85 | -0.57 | 0.75 | -1.39 |
| MCD | -2.20 | -1.82 | -2.63 | -1.42 | -0.32 | -1.40 | -1.38 | -1.09 | -1.83 |
| SLB | -2.45 | -2.13 | -3.87 | -2.61 | -2.15 | -2.88 | -3.08 | -1.61 | -2.92 |
| TXN | -0.67 | 0.72 | 0.42 | -0.85 | 0.58 | 0.41 | -0.23 | -0.73 | -1.17 |
| DOW | -1.50 | -0.48 | -2.87 | -0.40 | -0.05 | -0.31 | -1.09 | -0.07 | -1.78 |
| ABT | -2.10 | -1.01 | -1.84 | -0.98 | -0.23 | -1.40 | -0.13 | 1.98 | 0.06 |
| CL | 0.79 | 0.69 | -1.47 | -0.61 | 0.28 | -0.88 | -0.49 | 2.15 | 0.41 |
| BAC | 0.20 | 0.42 | -0.17 | -1.68 | -1.12 | -1.62 | -0.79 | -0.63 | -1.33 |
| UTX | 0.88 | 2.16 | 1.11 | -0.76 | 0.29 | -0.50 | 2.88 | 2.32 | 0.85 |
| EMR | -1.31 | -0.33 | -1.29 | -1.06 | -0.36 | -1.34 | 0.21 | 0.48 | -1.10 |
| MDT | -0.61 | 0.30 | -1.09 | 1.30 | 2.76 | 0.54 | 0.23 | 1.88 | -0.27 |
| UNH | -1.62 | -1.16 | -2.73 | -1.77 | -0.81 | -2.14 | -1.28 | -0.59 | -2.72 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 1009th to 1260th forecasting days.

Table B.22: DMW statistics of intraday volatility forecasts using the QLIKE loss function (1261-end)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.80 | 2.24 | 0.84 | 0.66 | 1.71 | 0.22 | -1.32 | -0.77 | -1.67 |
| GE | -1.35 | -0.16 | -0.79 | -0.57 | 1.10 | 0.37 | -1.34 | -1.05 | -2.08 |
| MO | -0.77 | 0.29 | -0.38 | 0.51 | 3.17 | 0.78 | -0.25 | 0.16 | -1.49 |
| MRK | -1.18 | -0.67 | -2.43 | -0.33 | 0.41 | -0.39 | -1.16 | 0.05 | -1.06 |
| KO | 1.17 | 1.37 | 0.65 | -0.87 | 0.41 | 0.24 | -1.33 | -0.42 | -0.45 |
| PFE | -0.39 | 0.59 | 0.79 | 0.72 | 3.66 | 3.91 | 3.26 | 2.36 | 0.97 |
| JNJ | 0.45 | 1.63 | 1.03 | 0.15 | 4.09 | 3.68 | 0.13 | 0.84 | 0.50 |
| AIG | 1.25 | 2.33 | 0.42 | 0.36 | 0.94 | -0.20 | -1.52 | -0.45 | -1.11 |
| PG | -1.28 | 0.23 | -0.06 | 0.52 | 4.23 | 3.67 | 0.67 | -0.29 | -0.87 |
| WMT | -0.11 | 0.86 | -0.83 | 1.47 | 3.31 | 1.45 | -0.39 | 0.68 | -0.59 |
| JPM | -0.78 | -0.09 | -1.53 | -1.13 | -0.40 | -1.96 | -2.34 | -2.09 | -2.58 |
| PEP | 1.13 | 0.74 | -0.55 | 0.99 | 3.95 | 2.84 | -2.16 | -0.57 | -0.83 |
| DD | 0.15 | 0.70 | -0.69 | -0.25 | 1.29 | 0.18 | -0.66 | 0.51 | -0.66 |
| DIS | -0.87 | -0.91 | -2.47 | -0.87 | -0.91 | -2.47 | -0.87 | -0.91 | -2.47 |
| HD | -0.95 | 1.12 | -0.35 | -2.38 | -0.94 | -1.46 | -0.65 | -0.20 | -1.05 |
| BA | -1.56 | -1.23 | -1.09 | -0.61 | 0.91 | 0.14 | -2.02 | -1.05 | -1.83 |
| MMM | -1.19 | -0.22 | -1.37 | 0.02 | 0.37 | -1.37 | -0.77 | 0.43 | -0.77 |
| AXP | -0.22 | 0.06 | -0.35 | -0.98 | -0.92 | -1.96 | -2.12 | -2.32 | -0.84 |
| T | -2.07 | -1.79 | -2.80 | -2.05 | -0.97 | -2.20 | -2.37 | -2.04 | -3.34 |
| MCD | -0.06 | 0.84 | -0.78 | -1.31 | 0.20 | -0.66 | -1.09 | -0.33 | -0.93 |
| SLB | 0.36 | 1.12 | -0.07 | -0.18 | 0.43 | -0.62 | -2.91 | -2.37 | -2.72 |
| TXN | -0.17 | 1.33 | 0.62 | -1.98 | -0.38 | -0.91 | -0.99 | 1.33 | 0.81 |
| DOW | 0.00 | 1.21 | -0.38 | 0.08 | 0.08 | -0.72 | -0.52 | 0.37 | -1.31 |
| ABT | -1.00 | 0.85 | -0.44 | 0.40 | 1.77 | 0.69 | -1.82 | 0.33 | -0.30 |
| CL | -1.09 | -0.54 | -1.49 | -0.06 | 2.53 | 0.96 | -0.95 | 0.12 | -0.72 |
| BAC | -1.40 | 0.39 | -0.58 | -0.32 | 1.25 | -0.11 | -2.26 | -2.12 | -2.53 |
| UTX | 0.06 | -0.64 | -1.73 | -0.39 | 2.06 | 1.94 | -3.23 | -1.64 | -1.37 |
| EMR | -1.41 | -1.10 | -2.57 | -1.39 | 0.01 | -1.18 | -2.40 | -1.95 | -3.08 |
| MDT | -0.69 | -0.31 | -1.59 | -0.49 | 1.27 | -0.11 | -0.76 | 1.20 | -0.54 |
| UNH | -1.98 | -1.64 | -2.56 | -1.77 | -1.03 | -1.82 | -0.94 | 1.11 | -0.14 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from 1261th to the end forecasting day.

Table B.23: DMW statistics of intraday volatility forecasts using the QLIKE loss function (whole period)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.70 | 2.56 | 0.79 | -1.53 | 1.80 | 1.18 | -1.63 | -0.82 | -0.01 |
| GE | -1.34 | 0.45 | -0.99 | -2.01 | 0.76 | -0.27 | -1.45 | -1.34 | -2.43 |
| MO | -2.20 | -1.62 | -2.50 | -1.32 | -0.76 | -1.66 | -0.62 | 0.77 | -1.58 |
| MRK | -2.41 | -2.01 | -3.66 | -1.63 | 0.04 | -2.43 | -2.58 | -1.93 | -2.16 |
| KO | -1.36 | -0.40 | -0.87 | -1.72 | 1.17 | 0.40 | -2.69 | -1.05 | -1.11 |
| PFE | 0.39 | 1.33 | 0.30 | -2.19 | 1.27 | 1.32 | 0.57 | 0.54 | -0.66 |
| JNJ | -1.53 | 0.24 | -0.92 | -0.72 | 3.91 | 2.59 | -1.22 | 0.23 | -0.41 |
| AIG | -2.44 | -2.06 | -2.46 | -2.05 | -0.87 | -2.04 | -3.23 | -1.34 | -2.38 |
| PG | -2.64 | 0.46 | -0.38 | -1.45 | 4.65 | 3.55 | -2.01 | -0.64 | -1.25 |
| WMT | -1.12 | 0.78 | -1.92 | -1.01 | 3.59 | 1.19 | -1.62 | -0.07 | -1.06 |
| JPM | -2.17 | -1.46 | -2.69 | -1.86 | -0.12 | -0.95 | -2.34 | -1.89 | -2.66 |
| PEP | -0.58 | 1.18 | 0.78 | 0.09 | 3.92 | 2.86 | -1.56 | 0.61 | 0.31 |
| DD | -1.80 | -0.88 | -1.79 | -1.16 | 1.47 | 0.18 | -2.46 | -0.76 | -1.58 |
| DIS | -0.45 | -0.21 | 0.35 | -0.68 | 1.13 | 1.83 | -0.21 | 0.47 | 0.67 |
| HD | -0.82 | 0.77 | -1.22 | -3.19 | 0.53 | -0.84 | -2.12 | -0.74 | -2.24 |
| BA | -0.93 | -1.21 | -1.56 | -2.24 | 1.02 | 0.46 | -2.11 | -0.04 | -0.66 |
| MMM | -3.54 | -2.20 | -3.75 | -2.29 | -0.59 | -2.00 | -2.62 | -1.40 | -3.12 |
| AXP | -2.24 | -2.09 | -2.63 | -3.21 | -1.11 | -1.84 | -3.02 | -3.14 | -2.79 |
| T | -3.26 | -2.49 | -4.65 | -3.20 | -0.99 | -2.20 | -2.69 | -1.54 | -3.41 |
| MCD | -2.65 | -2.09 | -3.17 | -0.83 | 0.39 | -0.96 | -1.11 | -0.32 | -1.10 |
| SLB | -2.71 | -2.17 | -3.72 | -3.92 | -1.35 | -2.21 | -3.96 | -1.14 | -2.19 |
| TXN | -2.87 | -1.23 | -1.78 | -3.13 | 0.50 | -0.53 | -2.25 | 0.38 | 0.16 |
| DOW | -1.26 | -0.88 | -3.09 | -1.28 | -0.75 | -1.15 | -2.68 | -1.74 | -2.86 |
| ABT | -2.26 | -1.38 | -2.82 | -2.12 | 1.27 | -0.21 | -3.12 | -0.21 | -1.04 |
| CL | -2.17 | -2.21 | -4.21 | -1.63 | 2.20 | -0.66 | -1.75 | -0.16 | -1.64 |
| BAC | -1.46 | -0.21 | -1.15 | -2.25 | 0.71 | 0.11 | -3.01 | -2.84 | -3.37 |
| UTX | -2.64 | -2.08 | -2.48 | 0.77 | 1.50 | -0.67 | -2.72 | -1.77 | -1.96 |
| EMR | -3.39 | -2.16 | -0.51 | -3.18 | -0.61 | -1.32 | -2.47 | -1.77 | -3.47 |
| MDT | -1.40 | -0.49 | -1.36 | -1.03 | 2.43 | -0.53 | -2.22 | 1.24 | -1.63 |
| UNH | -3.86 | -3.22 | -4.78 | -3.21 | -0.26 | -2.52 | -1.96 | 0.14 | -1.62 |

Note: The benchmark model is HAR-MEM-OJ (ICV) with $s_i^E$. All models use HAR-MEM-OJ as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period includes whole forecasting days.

Table B.24: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (1-252)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.72 | 1.73 | -0.45 | -0.49 | 1.53 | 0.67 | -0.57 | -0.69 | 0.92 |
| GE | -0.89 | -0.58 | -1.33 | 1.30 | 1.63 | -0.66 | 0.34 | 0.18 | -1.62 |
| MO | -0.88 | -1.28 | 0.74 | 1.11 | 1.73 | -1.01 | 1.72 | 2.60 | 1.85 |
| MRK | 0.77 | 1.01 | -0.08 | -0.44 | 2.51 | -1.41 | 1.48 | 1.84 | -1.17 |
| KO | -1.05 | -1.03 | -2.09 | -1.22 | -0.69 | -1.09 | -1.70 | -1.19 | -1.80 |
| PFE | 0.60 | 1.03 | 1.54 | 0.99 | 3.60 | 4.67 | 1.94 | 1.81 | -0.32 |
| JNJ | 1.37 | 1.59 | 0.11 | 1.06 | 1.63 | 2.35 | 0.83 | 1.03 | -0.94 |
| AIG | -1.46 | -1.42 | -2.12 | -1.52 | -0.39 | -1.68 | -0.22 | 0.64 | -1.59 |
| PG | 0.07 | 0.74 | -0.44 | 1.53 | 4.08 | 2.58 | -1.00 | 1.04 | -0.14 |
| WMT | -0.62 | -0.31 | 0.82 | -0.03 | 3.26 | 2.48 | 0.19 | 1.44 | -0.04 |
| JPM | 2.89 | 2.68 | -0.85 | 0.93 | 1.83 | -0.23 | 0.16 | 1.64 | -0.25 |
| PEP | -0.18 | 1.04 | 0.82 | 1.41 | 3.98 | 2.67 | -0.38 | 0.51 | 0.15 |
| DD | -0.67 | -0.66 | 0.38 | 1.00 | 1.16 | -0.80 | -0.75 | 0.95 | 0.24 |
| DIS | 0.71 | 0.82 | -1.09 | 1.25 | 1.41 | -0.33 | 1.07 | 1.20 | 0.05 |
| HD | -0.69 | -0.74 | -0.95 | -0.05 | 1.47 | -0.25 | -1.20 | 0.09 | -1.24 |
| BA | -0.87 | -0.92 | 1.52 | -1.02 | -0.17 | -0.97 | -1.11 | -0.88 | -1.12 |
| MMM | -1.90 | -1.50 | -2.34 | -0.16 | 0.69 | -1.24 | -0.67 | 0.70 | -1.26 |
| AXP | 0.47 | 1.35 | -1.61 | 0.85 | 2.19 | 0.31 | 0.77 | 1.50 | -1.06 |
| T | -0.19 | 0.44 | -1.60 | 0.18 | 1.50 | 0.70 | -0.99 | 0.40 | -1.58 |
| MCD | -0.27 | 0.61 | -0.66 | 1.78 | 3.50 | 1.68 | 0.09 | 1.59 | 0.66 |
| SLB | -1.52 | -1.00 | -2.04 | -2.01 | -0.36 | -1.58 | -1.77 | -0.45 | -1.53 |
| TXN | -1.52 | -1.08 | -1.70 | -0.68 | 0.57 | -1.13 | -1.16 | -1.12 | -1.23 |
| DOW | 0.10 | 0.05 | -1.61 | -0.67 | -0.33 | -0.77 | -0.30 | 0.85 | -0.16 |
| ABT | 1.05 | 1.56 | 1.12 | -0.43 | 0.99 | 0.90 | -1.08 | 0.19 | 0.05 |
| CL | 0.44 | 0.40 | 0.60 | -0.43 | 0.46 | -0.68 | -0.68 | 1.51 | -0.26 |
| BAC | 1.90 | 1.76 | -1.54 | -1.00 | -0.52 | -1.65 | -0.07 | 0.11 | -1.07 |
| UTX | -1.19 | -1.12 | -1.21 | -0.57 | 0.02 | -0.85 | -1.01 | -0.77 | -1.49 |
| EMR | -1.47 | -1.67 | 2.32 | -1.48 | -1.49 | -1.56 | -0.88 | -0.13 | -2.49 |
| MDT | 0.48 | 0.16 | 1.44 | 1.37 | 2.11 | -0.22 | -1.50 | 0.94 | -1.78 |
| UNH | 0.08 | 0.08 | 1.11 | 1.29 | 3.29 | 0.77 | 1.30 | 4.12 | 2.45 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the first to 252th forecasting day.

Table B.25: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (253-504)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -0.86 | -0.85 | -2.33 | -1.93 | -1.17 | -1.37 | -0.43 | -0.96 | 1.41 |
| GE | -0.56 | -0.18 | -0.04 | -1.06 | 0.01 | -0.87 | -0.92 | -0.52 | 1.63 |
| MO | -0.07 | 0.74 | -1.27 | -0.08 | 0.24 | -1.14 | 0.69 | 1.59 | -0.34 |
| MRK | -1.37 | -0.44 | -2.18 | 1.54 | 2.31 | -0.36 | -1.36 | -1.22 | -1.58 |
| KO | 0.58 | 1.05 | -0.68 | -0.15 | 2.00 | 0.07 | -1.12 | -0.86 | -1.33 |
| PFE | -0.23 | 2.33 | 1.08 | -1.40 | 0.69 | -0.13 | -1.35 | -1.01 | -0.75 |
| JNJ | 0.11 | 1.06 | -1.21 | 0.63 | 1.79 | 1.94 | -1.37 | -1.33 | -1.56 |
| AIG | -1.08 | -1.06 | -1.83 | -1.14 | 1.27 | -1.78 | -1.46 | -1.43 | -2.17 |
| PG | -0.66 | 1.26 | -0.52 | -0.97 | 1.84 | 0.71 | -1.26 | -1.01 | -1.16 |
| WMT | -0.90 | -0.33 | -1.16 | -1.46 | 0.88 | -0.69 | -1.39 | -1.41 | -1.81 |
| JPM | -0.86 | -0.80 | -1.10 | -1.15 | -0.79 | -1.14 | 0.51 | 0.77 | -1.64 |
| PEP | -0.91 | 0.11 | -0.20 | -0.10 | 2.08 | 2.41 | -1.41 | -0.70 | -0.67 |
| DD | -1.27 | -1.16 | -1.56 | -1.41 | -0.11 | -0.91 | -1.52 | -1.24 | -1.60 |
| DIS | -1.64 | -1.34 | -1.05 | -0.59 | 0.41 | 0.52 | -1.36 | 0.61 | 1.18 |
| HD | -1.15 | -0.90 | -0.82 | -1.03 | 0.08 | -0.28 | -1.56 | -1.52 | -1.54 |
| BA | -1.48 | -1.15 | -1.00 | -0.67 | 2.89 | 1.51 | -0.78 | 0.24 | 0.87 |
| MMM | -0.99 | -0.72 | -1.03 | -1.24 | -0.67 | -0.99 | -1.62 | -1.60 | -1.99 |
| AXP | -0.40 | -0.96 | 1.40 | -1.86 | 0.82 | -1.17 | -0.08 | 0.27 | -0.47 |
| T | -1.22 | -0.83 | -1.68 | -1.34 | 1.04 | -0.52 | -0.16 | 0.70 | -0.36 |
| MCD | -1.38 | -1.37 | -1.88 | -1.01 | 0.24 | -0.64 | -0.64 | 0.82 | -0.25 |
| SLB | -1.46 | -1.37 | -1.68 | -1.74 | 1.15 | -0.16 | -0.58 | 1.19 | 0.38 |
| TXN | -1.85 | -1.51 | -3.20 | -1.90 | 0.43 | -0.93 | -1.30 | -0.17 | -0.79 |
| DOW | -1.49 | -1.49 | -2.34 | 0.76 | 1.90 | 0.01 | -1.55 | -1.29 | -1.59 |
| ABT | -1.57 | -1.46 | -2.28 | 0.01 | 1.67 | -0.15 | -1.85 | -1.55 | -1.92 |
| CL | -1.19 | -0.45 | -2.12 | -0.46 | 1.57 | -1.19 | -1.60 | -1.30 | -1.60 |
| BAC | -1.11 | -0.99 | -1.35 | -1.36 | -0.70 | -0.76 | -0.32 | -0.20 | -1.39 |
| UTX | -2.11 | -2.09 | -2.61 | -1.75 | -0.24 | -1.36 | -1.38 | -1.47 | 0.17 |
| EMR | -1.41 | -1.61 | 3.08 | -0.94 | -0.44 | -0.85 | -1.36 | -1.22 | -1.75 |
| MDT | -0.40 | 0.17 | -0.59 | -1.26 | 1.74 | -0.66 | -1.12 | -0.67 | -1.16 |
| UNH | -2.11 | -1.83 | -2.10 | -0.76 | 1.70 | -0.19 | -1.07 | -0.36 | -1.42 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 253th to 504th forecasting day.

Table B.26: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (504-756)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 2.27 | 3.03 | 1.36 | -0.37 | 3.12 | 2.93 | 0.37 | -0.59 | -1.23 |
| GE | 0.30 | 3.16 | 3.20 | -0.78 | 2.20 | 3.24 | 0.43 | 1.09 | 0.73 |
| MO | 1.36 | 1.52 | -1.05 | 0.39 | 1.25 | 0.12 | 1.66 | 2.01 | 1.30 |
| MRK | 0.43 | 0.34 | -0.81 | 1.07 | 2.04 | 0.74 | 0.26 | 2.56 | 1.68 |
| KO | 0.64 | 2.39 | 1.77 | -0.18 | 1.91 | 1.08 | 1.45 | 3.91 | 3.56 |
| PFE | 1.18 | 2.06 | 1.11 | 0.87 | 3.96 | 3.17 | 1.09 | 3.17 | 2.79 |
| JNJ | 0.02 | 0.95 | 0.06 | 1.05 | 3.47 | 2.81 | 3.17 | 4.50 | 2.97 |
| AIG | 1.38 | 1.97 | 1.79 | -0.19 | 2.19 | 1.85 | 0.07 | 0.96 | 1.69 |
| PG | -0.10 | 1.94 | 1.43 | 2.24 | 4.59 | 4.04 | -0.49 | 1.52 | 1.85 |
| WMT | 0.78 | 2.11 | 1.09 | 0.10 | 3.03 | 2.23 | -0.35 | -0.39 | -1.24 |
| JPM | -2.18 | -1.62 | -0.50 | 0.12 | 2.73 | 3.61 | -1.42 | 0.40 | 2.42 |
| PEP | -2.94 | 1.50 | 3.10 | -0.16 | 2.87 | 3.06 | -1.90 | 3.95 | 3.82 |
| DD | -0.62 | 1.09 | 1.74 | -0.78 | 3.99 | 4.02 | -0.60 | 2.70 | 2.44 |
| DIS | -1.12 | 0.74 | 3.42 | -1.24 | 2.55 | 3.77 | -0.57 | 3.15 | 4.84 |
| HD | 1.69 | 1.44 | -0.24 | 0.36 | 1.31 | 1.02 | -0.05 | 0.30 | 0.18 |
| BA | 1.20 | 0.65 | -0.57 | -0.75 | 5.65 | 5.65 | -0.22 | 4.12 | 4.25 |
| MMM | 0.69 | 1.42 | -0.10 | -1.36 | 2.84 | 2.05 | 1.26 | 1.01 | -1.01 |
| AXP | -0.93 | -1.02 | 0.51 | -0.60 | 1.98 | 2.12 | 0.17 | 1.22 | 1.07 |
| T | 0.29 | 0.24 | 0.02 | 0.21 | 0.85 | 0.70 | 0.55 | 1.96 | 1.72 |
| MCD | 0.91 | 1.26 | -0.10 | 2.10 | 2.13 | 0.08 | 1.55 | 1.80 | -0.47 |
| SLB | -0.34 | -0.88 | -1.60 | -0.41 | 5.66 | 5.34 | -1.99 | 3.85 | 3.72 |
| TXN | -0.16 | 0.16 | 0.31 | -0.42 | 2.20 | 2.71 | -1.50 | 2.93 | 2.77 |
| DOW | -1.36 | -1.28 | -0.54 | 0.18 | 2.49 | 2.80 | -1.17 | 1.29 | 2.49 |
| ABT | 1.63 | 0.77 | -0.69 | 0.84 | 3.55 | 2.59 | 1.04 | 3.81 | 3.20 |
| CL | -0.89 | -1.16 | -1.57 | 0.91 | 5.27 | 3.47 | 2.51 | 3.12 | 1.15 |
| BAC | 0.18 | 0.88 | 0.98 | -1.57 | 2.69 | 2.98 | 0.97 | 0.73 | -0.54 |
| UTX | -0.82 | -0.91 | -0.80 | -0.17 | 2.53 | 1.65 | 1.54 | 2.93 | 2.36 |
| EMR | 1.49 | 1.07 | -0.37 | -0.71 | 2.88 | 2.94 | 0.34 | 1.69 | 2.16 |
| MDT | 0.69 | 1.15 | 0.64 | 1.23 | 2.25 | 1.30 | 1.11 | 3.45 | 2.55 |
| UNH | 0.70 | 1.41 | -0.66 | 0.03 | 4.13 | 1.00 | 1.12 | 3.59 | 1.14 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 505th to 756th forecasting day.

Table B.27: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (757-1008)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 3.08 | 4.43 | 3.74 | 1.70 | 2.94 | 2.72 | 1.95 | 2.00 | 0.27 |
| GE | 2.70 | 4.06 | 1.95 | 0.81 | 3.39 | 2.33 | 0.71 | 0.61 | -1.26 |
| MO | 0.84 | 1.12 | -1.49 | -0.69 | -0.59 | -1.47 | 1.18 | 2.00 | -1.48 |
| MRK | 0.85 | 0.93 | -1.42 | -0.02 | 0.95 | -1.98 | 1.49 | 1.73 | -1.37 |
| KO | -1.25 | -0.33 | -0.73 | -0.15 | 1.57 | 2.28 | 0.09 | 1.39 | 0.20 |
| PFE | 0.52 | 1.14 | -1.26 | -0.84 | -0.22 | -1.31 | 1.50 | 1.55 | -1.51 |
| JNJ | 0.74 | 1.65 | 0.00 | 1.34 | 2.32 | 1.24 | 2.72 | 3.81 | 1.53 |
| AIG | -1.64 | -0.97 | -1.20 | 1.08 | 1.51 | -0.68 | 1.17 | 1.33 | 0.51 |
| PG | -2.32 | -1.22 | -2.11 | -0.45 | 2.50 | -0.14 | 0.32 | 0.93 | -0.90 |
| WMT | -0.17 | 0.49 | -0.31 | 1.59 | 2.90 | 1.52 | 2.49 | 3.68 | 1.98 |
| JPM | -0.31 | 1.19 | -0.47 | -0.39 | 1.04 | 0.06 | 0.68 | 1.02 | -0.53 |
| PEP | -0.68 | 1.81 | 0.71 | -0.97 | 0.92 | 0.12 | 1.84 | 4.52 | 2.79 |
| DD | -0.36 | 0.10 | 0.12 | 2.20 | 3.86 | 2.52 | 0.39 | 2.76 | 3.18 |
| DIS | -0.08 | 1.70 | 2.03 | -0.91 | 2.66 | 3.49 | 0.95 | -0.40 | -0.55 |
| HD | 0.23 | 0.61 | 0.30 | -0.57 | 2.28 | 1.50 | 2.21 | 3.24 | 1.89 |
| BA | 2.24 | 2.36 | -0.59 | 0.39 | 2.23 | 1.54 | 1.05 | 1.90 | 0.22 |
| MMM | -0.99 | 0.39 | -0.89 | -0.56 | 0.77 | -0.92 | 0.13 | 0.31 | -1.51 |
| AXP | 1.01 | 0.89 | -1.31 | -0.30 | -0.18 | -1.19 | 1.33 | 1.13 | -0.45 |
| T | -0.26 | 0.01 | -0.57 | -0.10 | 1.79 | 1.43 | 1.20 | 1.91 | 0.83 |
| MCD | 0.66 | 1.90 | 1.75 | 2.97 | 4.30 | 2.97 | 2.85 | 4.96 | 2.58 |
| SLB | 0.83 | 0.97 | -1.62 | -1.34 | 0.82 | -0.96 | 1.11 | 2.53 | 0.68 |
| TXN | -0.51 | 0.23 | -0.70 | 0.62 | 3.31 | 0.91 | 1.41 | 3.01 | 1.62 |
| DOW | 1.53 | 1.34 | -0.11 | -0.71 | -0.08 | -1.51 | 1.21 | 1.53 | -0.46 |
| ABT | -0.28 | 0.48 | 0.15 | -0.34 | 1.15 | -0.11 | -0.63 | 0.80 | 0.34 |
| CL | -1.10 | -0.70 | -2.21 | 0.04 | 1.45 | -1.27 | -0.88 | 1.13 | -0.59 |
| BAC | 1.61 | 1.61 | -0.25 | -0.77 | 2.11 | 2.87 | -1.22 | -1.38 | -1.47 |
| UTX | 1.39 | 1.94 | 0.63 | 0.62 | 1.80 | 0.69 | 0.55 | 1.40 | -0.29 |
| EMR | 0.86 | 1.65 | 0.37 | -0.55 | 1.44 | 0.77 | 1.37 | 1.90 | 0.84 |
| MDT | 0.63 | 0.68 | 1.13 | 0.43 | 1.79 | -0.60 | 1.73 | 3.26 | 1.08 |
| UNH | -1.17 | -1.08 | -2.10 | 0.46 | 1.24 | -1.64 | 1.10 | 1.37 | -1.26 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 757th to 1008th forecasting day.

Table B.28: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (1009-1260)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -0.09 | 0.64 | -0.53 | -0.85 | -0.01 | -0.78 | 0.36 | 1.56 | 0.53 |
| GE | 2.00 | 3.25 | 1.51 | 1.40 | 3.05 | 1.92 | 1.89 | 2.04 | 0.07 |
| MO | -0.22 | 0.41 | -1.75 | 1.58 | 1.91 | 1.61 | 1.75 | 2.06 | -1.53 |
| MRK | 1.80 | 1.90 | -0.95 | 1.72 | 1.96 | 0.44 | 0.52 | 0.39 | -1.50 |
| KO | 0.31 | 0.80 | 1.05 | 1.00 | 3.20 | 2.95 | -0.80 | 2.62 | 3.72 |
| PFE | -0.37 | 0.93 | 0.58 | 1.50 | 2.44 | 1.02 | 0.59 | 1.15 | 0.04 |
| JNJ | -0.64 | -0.03 | -0.61 | -1.38 | -0.22 | -0.54 | 0.50 | 2.45 | 0.94 |
| AIG | 0.59 | 0.79 | -1.34 | -0.91 | -0.74 | -0.88 | 1.11 | 1.88 | -0.47 |
| PG | -0.12 | 0.25 | -0.78 | 1.52 | 2.37 | -0.04 | -0.85 | -0.25 | -0.92 |
| WMT | -0.01 | 0.92 | -1.13 | -0.71 | 2.15 | -0.62 | -0.16 | 2.91 | 0.48 |
| JPM | -0.67 | 0.04 | -1.17 | -0.45 | 1.34 | -0.29 | 2.06 | 2.24 | 0.33 |
| PEP | 3.57 | 4.19 | 1.74 | 0.52 | 2.30 | 0.83 | 2.88 | 5.26 | 2.69 |
| DD | 1.37 | 1.53 | -2.06 | 0.26 | 0.33 | -1.63 | -1.27 | -0.20 | -1.66 |
| DIS | 2.95 | 3.08 | 1.35 | 0.83 | 1.48 | 0.60 | 2.40 | 3.96 | 1.68 |
| HD | 1.77 | 2.82 | 0.20 | 0.40 | 2.32 | -0.62 | -0.01 | 1.37 | -1.28 |
| BA | 0.56 | 0.47 | -1.73 | 0.92 | 2.68 | 0.28 | 1.16 | 1.60 | -0.35 |
| MMM | -0.89 | -0.35 | -1.51 | 1.30 | 2.20 | -0.92 | 0.47 | 2.18 | -0.70 |
| AXP | 0.55 | 0.89 | -1.63 | -1.40 | -0.95 | -2.40 | -0.94 | -0.92 | -2.07 |
| T | -1.35 | -0.62 | -1.35 | -0.63 | 1.35 | 0.13 | -0.87 | 0.90 | -0.37 |
| MCD | -1.25 | -0.62 | -1.95 | -0.78 | 0.85 | -0.87 | -1.08 | -0.45 | -1.58 |
| SLB | -0.94 | -0.47 | -3.57 | -2.02 | -1.59 | -2.51 | -2.04 | -0.23 | -2.34 |
| TXN | 0.93 | 2.35 | 1.03 | -1.01 | 0.90 | 0.81 | 0.20 | 1.49 | 0.15 |
| DOW | 0.88 | 1.97 | -2.28 | -0.26 | -0.04 | -0.60 | 1.24 | 2.88 | -1.12 |
| ABT | -0.82 | 0.24 | -1.77 | 1.02 | 1.85 | -0.69 | 1.52 | 3.15 | 1.29 |
| CL | 1.37 | 1.48 | -0.74 | 0.92 | 1.92 | -0.08 | -0.10 | 3.72 | 0.27 |
| BAC | 1.58 | 1.97 | 1.34 | -1.03 | 0.28 | -1.21 | 0.52 | 0.81 | -1.06 |
| UTX | 0.53 | 1.93 | 0.56 | -0.28 | 1.04 | -0.16 | 2.45 | 2.93 | 1.49 |
| EMR | -0.03 | 1.20 | -0.58 | -0.59 | 0.42 | -0.98 | -0.92 | 0.90 | -0.76 |
| MDT | 0.62 | 1.54 | -0.74 | 1.43 | 3.75 | 1.02 | 2.15 | 3.96 | 1.04 |
| UNH | -0.76 | -0.27 | -1.88 | -0.84 | 0.68 | -2.04 | 1.25 | 2.30 | -1.95 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 1009th to 1261th forecasting day.

Table B.29: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (1261-end)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.13 | 2.60 | 0.95 | 1.52 | 2.68 | 0.04 | 0.11 | 0.89 | -1.32 |
| GE | 1.12 | 1.78 | 1.14 | 1.71 | 2.95 | 2.56 | -1.01 | -0.72 | -1.69 |
| MO | 1.14 | 1.79 | -0.38 | 1.36 | 1.97 | 1.75 | 0.92 | 1.25 | -1.57 |
| MRK | 1.11 | 2.03 | -2.02 | 1.60 | 2.86 | 0.38 | -0.62 | 0.80 | -1.25 |
| KO | 2.22 | 2.39 | 1.70 | -0.12 | 0.88 | 0.00 | -1.35 | 0.26 | -0.44 |
| PFE | 0.24 | 2.04 | 1.97 | 1.73 | 4.87 | 5.37 | 3.04 | 4.13 | 2.01 |
| JNJ | 1.88 | 2.67 | 2.30 | 1.27 | 4.03 | 3.96 | -0.87 | -0.11 | -0.33 |
| AIG | 1.56 | 1.95 | 0.50 | 0.96 | 1.53 | -0.86 | 0.45 | 1.01 | -1.38 |
| PG | 0.94 | 2.70 | 2.02 | 0.16 | 4.11 | 3.98 | -0.08 | 0.23 | -0.90 |
| WMT | 1.98 | 2.87 | 0.81 | 2.42 | 3.82 | 2.40 | 1.06 | 2.33 | 0.79 |
| JPM | 0.73 | 1.34 | 0.25 | 1.19 | 1.65 | 0.30 | -0.03 | 0.69 | -1.72 |
| PEP | 2.51 | 2.94 | 0.76 | 1.73 | 4.29 | 2.90 | -1.64 | -0.26 | -0.91 |
| DD | 2.06 | 2.45 | 1.26 | 0.21 | 1.79 | 0.22 | -0.29 | 1.42 | -0.70 |
| DIS | 0.13 | 0.35 | -1.97 | 0.27 | 1.48 | 0.74 | -0.77 | -0.36 | -1.09 |
| HD | 1.57 | 2.88 | 1.87 | -1.74 | -0.12 | -1.29 | -0.84 | -0.31 | -1.40 |
| BA | -0.83 | -0.32 | -0.64 | -0.27 | 1.30 | -0.10 | -1.97 | -0.93 | -2.10 |
| MMM | 0.55 | 1.57 | 0.15 | -0.26 | 0.11 | -1.26 | 0.78 | 2.47 | -0.79 |
| AXP | 1.75 | 2.08 | 1.56 | 1.09 | 1.31 | 0.04 | -0.69 | -0.81 | -1.01 |
| T | 0.67 | 0.87 | -0.48 | 0.57 | 1.36 | 1.01 | -0.83 | -0.04 | -1.95 |
| MCD | 1.09 | 2.22 | 0.79 | -0.72 | 0.84 | 0.12 | -0.88 | -0.24 | -0.87 |
| SLB | 0.67 | 1.66 | 0.44 | 0.60 | 1.32 | -0.15 | -2.27 | -1.63 | -2.22 |
| TXN | 0.49 | 1.84 | 1.00 | -0.91 | 0.46 | -0.70 | 0.33 | 2.66 | 1.58 |
| DOW | 1.35 | 2.24 | 1.52 | 1.78 | 2.50 | 0.00 | -0.77 | 0.70 | -1.22 |
| ABT | -0.94 | 0.50 | -0.67 | 1.79 | 2.56 | 1.55 | -1.72 | 0.36 | -0.61 |
| CL | 0.90 | 1.96 | -0.30 | 0.28 | 3.16 | 1.03 | -1.39 | 0.40 | -0.76 |
| BAC | 0.13 | 1.35 | 0.31 | 1.20 | 2.40 | 0.95 | -1.02 | -0.58 | -1.12 |
| UTX | 0.23 | 0.54 | -1.09 | -0.90 | 1.25 | 0.83 | -2.26 | -1.47 | -1.60 |
| EMR | -1.34 | 0.05 | -2.10 | -1.06 | 0.68 | -0.21 | -1.52 | -1.20 | -1.78 |
| MDT | -0.55 | 0.54 | -0.70 | 0.87 | 3.65 | 0.40 | -0.32 | 2.78 | 0.06 |
| UNH | -1.47 | -0.15 | -2.56 | -0.57 | 0.81 | -1.33 | 0.29 | 2.74 | -0.35 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 1261th to the end of forecasting days.

Table B.30: DMW statistics of intraday volatility forecasts without overnight jump using the MSE loss function (whole period)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.46 | 1.49 | -0.87 | -1.83 | -0.31 | -0.89 | -0.68 | -0.94 | 1.46 |
| GE | -0.96 | -0.42 | -0.98 | -0.39 | 0.89 | -0.80 | -0.64 | -0.33 | -0.42 |
| MO | 0.91 | 2.08 | -1.86 | 0.67 | 1.62 | -1.44 | 2.49 | 3.47 | 0.48 |
| MRK | 0.29 | 1.41 | -2.54 | 1.91 | 3.41 | -0.92 | -1.01 | -0.74 | -2.51 |
| KO | -0.07 | 0.61 | -1.45 | -1.16 | 1.17 | -0.54 | -1.44 | -1.06 | -1.82 |
| PFE | 0.36 | 3.03 | 1.32 | -1.31 | 1.50 | 0.78 | -0.55 | -0.08 | -0.64 |
| JNJ | 0.82 | 1.48 | -0.95 | 1.19 | 2.21 | 2.95 | -1.22 | -1.01 | -1.47 |
| AIG | -1.08 | -0.96 | -2.31 | -1.28 | 1.21 | -1.98 | -1.28 | -0.90 | -2.43 |
| PG | -0.61 | 1.56 | -0.53 | -0.32 | 4.32 | 3.04 | -1.41 | -0.64 | -1.13 |
| WMT | -0.93 | -0.06 | -0.91 | -1.23 | 1.73 | -0.01 | -1.33 | -1.22 | -1.38 |
| JPM | -0.73 | -0.64 | -1.15 | -1.07 | -0.53 | -1.06 | 0.51 | 0.92 | -1.68 |
| PEP | -0.91 | 0.55 | 0.49 | 0.60 | 2.59 | 3.24 | -1.45 | -0.38 | -0.19 |
| DD | -1.22 | -1.03 | -1.35 | -1.01 | 0.62 | -0.70 | -1.60 | -0.82 | -1.22 |
| DIS | 0.04 | 0.32 | -0.77 | 0.56 | 1.51 | 1.01 | 0.78 | 1.31 | 2.02 |
| HD | -1.16 | -0.80 | -0.72 | -1.01 | 0.64 | -0.28 | -1.73 | -1.24 | -1.79 |
| BA | -1.46 | -1.40 | -0.93 | -1.15 | 2.13 | 2.06 | -1.32 | -0.58 | 0.31 |
| MMM | -2.06 | -1.44 | -2.43 | -1.09 | 0.12 | -1.50 | -1.61 | -0.55 | -2.29 |
| AXP | 0.10 | 0.71 | 0.41 | -0.50 | 2.19 | -0.84 | 0.18 | 1.29 | -1.10 |
| T | -1.18 | -0.77 | -1.73 | -1.13 | 1.38 | -0.33 | -0.31 | 0.89 | -0.36 |
| MCD | -1.30 | -1.14 | -1.86 | -0.55 | 1.41 | -0.15 | -0.22 | 1.92 | 0.00 |
| SLB | -1.87 | -1.26 | -2.53 | -2.37 | 0.59 | -1.22 | -2.76 | 0.00 | -1.59 |
| TXN | -2.00 | -1.43 | -2.68 | -1.35 | 0.88 | -1.15 | -1.44 | -0.88 | -0.79 |
| DOW | -1.24 | -1.17 | -2.51 | -0.40 | 0.57 | -0.61 | -1.48 | -0.56 | -1.41 |
| ABT | -1.43 | -1.20 | -2.05 | 0.13 | 2.16 | 0.84 | -1.84 | -1.12 | -1.30 |
| CL | -0.61 | -0.18 | -1.58 | -0.48 | 2.33 | -0.75 | -1.60 | -0.70 | -1.52 |
| BAC | -0.25 | -0.28 | -1.39 | -1.57 | -0.55 | -1.44 | -0.77 | -0.27 | -1.49 |
| UTX | -1.96 | -1.90 | -2.38 | -1.00 | 0.04 | -1.20 | -1.31 | -1.00 | -1.44 |
| EMR | -1.97 | -2.07 | 2.98 | -1.46 | -0.63 | -0.81 | -1.59 | -1.29 | -2.69 |
| MDT | 0.07 | 0.47 | 1.03 | 0.32 | 2.86 | -0.44 | -1.24 | -0.19 | -1.50 |
| UNH | -2.34 | -1.85 | -3.04 | -0.38 | 3.35 | -0.33 | -0.09 | 1.94 | -0.84 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period includes whole forecasting days.

Table B.31: DMW statistics of intraday volatility forecasts without overnight jump using the QLIKE loss function (1-252)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 1.59 | 1.01 | -0.59 | -0.94 | 1.42 | 0.95 | -0.83 | -0.63 | 1.41 |
| GE | -1.67 | -1.76 | -2.78 | -0.58 | -0.78 | -1.86 | -1.15 | -1.23 | -1.78 |
| MO | -1.02 | -1.50 | 0.99 | 1.39 | 1.49 | -0.67 | 0.90 | 2.09 | 0.93 |
| MRK | -0.21 | 0.18 | -0.20 | -1.38 | -0.47 | -2.17 | -1.31 | -1.03 | -1.29 |
| KO | -2.12 | -2.03 | -2.77 | -1.19 | -0.45 | -1.00 | -2.50 | -1.78 | -2.04 |
| PFE | 0.16 | 1.25 | 1.65 | -0.54 | 3.18 | 3.02 | 2.60 | 1.20 | -0.98 |
| JNJ | 0.11 | 0.99 | 0.23 | 1.29 | 3.77 | 2.06 | -0.40 | 0.10 | -0.87 |
| AIG | -1.54 | -1.54 | -2.24 | -1.57 | -1.21 | -1.57 | -2.43 | -1.96 | -2.77 |
| PG | -0.79 | 0.49 | 0.26 | 0.94 | 3.06 | 2.38 | -0.58 | 1.22 | 0.61 |
| WMT | -0.33 | 0.78 | 1.38 | 1.25 | 4.69 | 3.82 | -0.28 | 0.28 | -0.31 |
| JPM | 0.47 | -0.67 | -1.51 | -0.56 | 0.70 | 0.01 | -0.74 | 0.10 | -0.36 |
| PEP | 0.58 | 2.27 | 1.95 | 1.39 | 4.62 | 2.16 | -0.47 | 0.35 | 0.20 |
| DD | -0.63 | -0.33 | 0.64 | -0.16 | -0.02 | -1.07 | -0.69 | 0.58 | -0.20 |
| DIS | -0.52 | -0.63 | -1.11 | 0.41 | 0.65 | -0.19 | -0.69 | 0.56 | 0.00 |
| HD | -1.37 | -1.53 | -1.48 | -0.84 | 1.12 | 0.75 | -1.85 | -0.92 | -1.30 |
| BA | -1.52 | -1.54 | 1.48 | -1.30 | -0.78 | -1.28 | -1.33 | -1.05 | -1.56 |
| MMM | -2.54 | -2.14 | -2.62 | -1.57 | -1.12 | -1.47 | -2.02 | -1.32 | -2.20 |
| AXP | -2.21 | -1.96 | -2.85 | -0.35 | 1.29 | 0.43 | -1.71 | -1.51 | -2.31 |
| T | -1.76 | -1.08 | -1.96 | 0.24 | 1.85 | 0.90 | -1.62 | -0.76 | -1.98 |
| MCD | -1.14 | -0.97 | -1.34 | 0.44 | 1.22 | 0.50 | -1.12 | 0.03 | -0.18 |
| SLB | -2.12 | -1.72 | -2.44 | -2.37 | -1.32 | -1.92 | -1.83 | -1.17 | -1.60 |
| TXN | -1.88 | -1.45 | -1.78 | -0.91 | 0.15 | -0.79 | -1.75 | -1.65 | -1.58 |
| DOW | -1.28 | -1.32 | -1.62 | -1.03 | -0.91 | -1.00 | -1.49 | -1.03 | -1.19 |
| ABT | 0.37 | 0.62 | -0.15 | -1.24 | 1.68 | 1.82 | -1.90 | -0.45 | -0.52 |
| CL | 0.53 | 0.63 | 0.66 | -1.24 | -0.07 | -0.87 | -1.65 | 0.40 | -0.58 |
| BAC | 0.31 | 0.09 | -0.56 | -0.94 | -1.12 | -1.79 | -1.02 | -0.99 | -1.68 |
| UTX | -1.73 | -1.66 | -1.91 | -0.97 | -0.87 | -0.99 | -1.48 | -1.37 | -1.98 |
| EMR | -2.26 | -2.19 | 3.02 | -2.96 | -2.94 | -2.24 | -1.75 | -1.34 | -2.57 |
| MDT | -1.16 | -1.48 | 1.68 | -0.23 | 0.74 | -0.24 | -2.98 | -1.37 | -2.71 |
| UNH | 0.15 | 0.20 | 0.92 | 0.35 | 2.18 | 0.68 | 0.85 | 3.22 | 1.87 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the first to 252th forecasting day.

Table B.32: DMW statistics of intraday volatility forecasts without overnight jump using the QLIKE loss function (253-504)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -1.80 | -1.70 | -2.14 | -1.68 | -0.67 | -0.91 | -1.25 | -1.59 | 1.73 |
| GE | -1.00 | -0.54 | -0.32 | -1.82 | -0.86 | -0.96 | -1.50 | -0.68 | 1.69 |
| MO | -0.84 | -0.50 | -1.42 | -1.06 | -0.78 | -0.92 | -1.44 | -0.24 | -0.42 |
| MRK | -2.99 | -2.60 | -3.46 | -1.49 | -0.20 | -1.20 | -1.76 | -1.45 | -1.78 |
| KO | -0.78 | -0.40 | -1.25 | -1.30 | 0.75 | -0.34 | -1.44 | -0.87 | -1.23 |
| PFE | -0.83 | 1.21 | 0.93 | -1.40 | 0.00 | -0.09 | -1.54 | -0.62 | -0.01 |
| JNJ | -1.64 | -1.10 | -1.80 | -0.88 | 1.45 | 0.70 | -1.68 | -1.62 | -1.91 |
| AIG | -2.19 | -2.18 | -2.99 | -1.70 | -0.51 | -2.09 | -2.54 | -2.42 | -3.44 |
| PG | -0.82 | 0.65 | -0.10 | -1.22 | 1.23 | 0.49 | -1.57 | -1.01 | -1.28 |
| WMT | -1.45 | -0.33 | -1.28 | -1.65 | 0.33 | -0.44 | -1.70 | -1.78 | -2.40 |
| JPM | -1.54 | -1.49 | -1.22 | -1.77 | -0.99 | -1.01 | -1.71 | -1.33 | -1.71 |
| PEP | -1.11 | -0.45 | -0.41 | -1.16 | 1.42 | 1.15 | -1.27 | -0.61 | -0.55 |
| DD | -1.92 | -1.59 | -2.07 | -1.42 | 0.09 | -0.47 | -1.61 | -1.25 | -1.52 |
| DIS | -2.01 | -1.35 | -0.49 | -0.67 | -0.14 | 0.03 | -1.69 | 0.65 | 1.44 |
| HD | -1.63 | -1.65 | -1.54 | -1.42 | 0.52 | 0.14 | -1.56 | -1.59 | -1.48 |
| BA | -1.98 | -1.18 | -0.84 | -2.06 | -0.17 | -0.26 | -0.80 | 1.09 | 1.53 |
| MMM | -1.30 | -0.71 | -1.25 | -1.18 | 0.22 | -0.29 | -2.19 | -2.01 | -2.16 |
| AXP | -1.76 | -2.38 | 1.69 | -2.26 | 0.19 | -0.59 | -1.21 | -0.70 | -0.12 |
| T | -2.03 | -1.66 | -2.42 | -2.09 | -1.26 | -1.67 | -1.41 | -1.01 | -1.40 |
| MCD | -2.29 | -2.11 | -2.09 | -1.38 | -0.57 | -0.87 | -1.37 | -0.09 | -0.63 |
| SLB | -1.75 | -1.43 | -1.53 | -2.34 | 0.16 | -0.31 | -1.35 | 0.66 | 0.30 |
| TXN | -2.50 | -2.55 | -3.45 | -2.01 | -0.29 | -0.71 | -1.26 | 0.02 | -0.22 |
| DOW | -1.71 | -1.72 | -2.80 | -1.13 | 0.66 | -0.53 | -2.03 | -1.85 | -2.22 |
| ABT | -1.97 | -1.88 | -2.87 | -1.74 | -0.26 | -1.34 | -2.44 | -1.65 | -1.94 |
| CL | -2.54 | -2.37 | -3.20 | -1.03 | 0.40 | -1.50 | -1.51 | -1.17 | -1.54 |
| BAC | -1.61 | -1.17 | -1.38 | -1.22 | 0.16 | 0.06 | -1.25 | -1.17 | -1.14 |
| UTX | -2.75 | -2.75 | -3.59 | -2.06 | -0.56 | -1.41 | -2.32 | -2.22 | -1.17 |
| EMR | -2.49 | -2.47 | 3.50 | -0.90 | 0.09 | 0.01 | -1.34 | -1.04 | -1.65 |
| MDT | -0.90 | -0.44 | -0.85 | -1.52 | 0.98 | -0.41 | -1.24 | -0.37 | -0.93 |
| UNH | -2.43 | -2.20 | -2.73 | -1.27 | 0.65 | -0.64 | -1.63 | -1.02 | -1.51 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 253th to 504th forecasting day.

Table B.33: DMW statistics of intraday volatility forecasts without overnight jump using the QLIKE loss function (505-756)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 2.01 | 2.77 | 1.30 | 0.06 | 4.04 | 4.08 | 0.08 | -0.68 | -0.80 |
| GE | -0.17 | 1.29 | 1.48 | -1.22 | 1.15 | 1.56 | -0.17 | -0.67 | -0.54 |
| MO | -1.09 | -0.44 | -0.79 | -1.72 | -0.45 | -1.05 | 0.09 | 1.54 | 0.96 |
| MRK | -0.13 | -0.24 | -0.91 | 0.10 | 0.76 | -0.05 | 0.03 | 2.27 | 1.57 |
| KO | 0.10 | 1.99 | 1.71 | -0.45 | 0.85 | 0.43 | 0.18 | 1.80 | 1.44 |
| PFE | -1.06 | -0.60 | -0.62 | 0.01 | 3.11 | 2.86 | 0.45 | 2.30 | 1.99 |
| JNJ | -0.17 | 0.26 | -0.41 | 0.75 | 1.95 | 1.19 | 2.01 | 3.17 | 2.33 |
| AIG | -0.17 | 0.38 | 0.19 | -0.04 | 1.52 | 1.09 | 0.06 | 1.03 | 0.81 |
| PG | -0.63 | 2.75 | 2.34 | 0.54 | 5.46 | 4.97 | -0.50 | 0.88 | 0.82 |
| WMT | -0.11 | 1.01 | 0.20 | -0.49 | 1.92 | 1.33 | -0.27 | -0.25 | -1.14 |
| JPM | -2.73 | -1.21 | 0.21 | 0.33 | 4.01 | 4.71 | -1.11 | -0.28 | 1.20 |
| PEP | -2.97 | 1.24 | 2.88 | -0.13 | 1.48 | 2.49 | -1.01 | 3.46 | 4.26 |
| DD | -0.40 | 0.49 | 0.63 | -0.16 | 3.03 | 2.96 | -0.88 | 0.72 | 0.95 |
| DIS | -0.87 | 1.18 | 4.57 | -1.31 | 1.98 | 3.69 | -1.96 | 5.82 | 9.03 |
| HD | 1.70 | 1.59 | -0.69 | -0.56 | 0.16 | 0.00 | -1.01 | -0.83 | -0.97 |
| BA | 1.33 | 0.29 | -1.01 | -0.55 | 4.24 | 4.83 | -1.33 | 4.80 | 5.61 |
| MMM | -0.32 | 0.21 | -0.42 | -1.79 | 0.86 | 0.18 | 0.22 | 0.16 | -0.95 |
| AXP | 0.30 | 0.29 | 0.41 | -0.90 | 1.12 | 1.18 | -1.04 | -0.64 | -0.38 |
| T | -0.27 | -0.60 | -0.59 | -0.75 | -0.06 | 0.20 | 1.72 | 0.06 | -0.29 |
| MCD | -0.24 | -0.06 | -0.71 | 0.22 | -0.35 | -0.65 | 1.23 | 1.22 | -0.18 |
| SLB | -0.45 | -1.33 | -2.24 | -0.46 | 5.56 | 5.46 | -1.00 | 3.04 | 3.04 |
| TXN | -0.07 | -0.11 | -0.79 | -0.67 | 0.92 | 0.96 | -1.88 | 0.63 | 0.76 |
| DOW | -0.88 | -1.11 | -1.10 | 0.01 | 2.15 | 2.28 | -1.58 | 0.05 | 0.64 |
| ABT | 1.56 | 0.77 | -0.45 | -0.07 | 2.16 | 1.73 | 0.49 | 3.26 | 2.64 |
| CL | -1.02 | -1.07 | -1.34 | -0.35 | 3.23 | 1.88 | 1.20 | 1.60 | -0.09 |
| BAC | 1.12 | 2.20 | 2.42 | -1.18 | 3.07 | 2.91 | 0.23 | -0.25 | -0.78 |
| UTX | -0.41 | -0.37 | -0.57 | -0.92 | 1.38 | 1.32 | -0.30 | 1.09 | 1.09 |
| EMR | -0.55 | -0.32 | -0.69 | -0.17 | 1.22 | 1.03 | 0.41 | 0.96 | 1.32 |
| MDT | 0.20 | 0.22 | -0.79 | 0.46 | 1.73 | 0.61 | 0.37 | 2.29 | 1.46 |
| UNH | -0.24 | 0.31 | -0.36 | -1.24 | 1.28 | -0.02 | 0.19 | 2.09 | 0.87 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 505th to 756th forecasting day.

Table B.34: DMW statistics of intraday volatility forecasts without overnight jump using the QLIKE loss function (757-1008)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 3.46 | 3.40 | 1.98 | 1.86 | 2.71 | 2.06 | 1.62 | 1.73 | 1.11 |
| GE | 1.55 | 2.48 | 0.60 | -0.54 | 1.56 | 0.85 | -0.03 | -0.12 | -1.35 |
| MO | -1.37 | -1.09 | -1.82 | -1.35 | -1.25 | -1.46 | -1.56 | -0.77 | -1.87 |
| MRK | -1.42 | -1.30 | -1.48 | -1.84 | -1.27 | -2.33 | -0.95 | -0.79 | -1.81 |
| KO | -1.43 | -0.80 | -1.14 | 0.26 | 2.20 | 1.65 | -0.26 | 0.67 | -0.10 |
| PFE | -1.20 | -0.84 | -1.36 | -2.13 | -1.26 | -1.67 | -1.53 | -1.19 | -1.69 |
| JNJ | -0.88 | 0.29 | -0.68 | 0.04 | 1.13 | 0.46 | 1.29 | 2.00 | 0.58 |
| AIG | -1.30 | -1.17 | -1.15 | 0.93 | -0.46 | -0.83 | 0.74 | 1.00 | -0.11 |
| PG | -2.94 | -1.11 | -1.80 | -1.31 | 0.59 | -0.82 | -0.21 | 0.37 | -0.77 |
| WMT | -0.33 | 0.26 | -0.83 | 0.78 | 1.68 | 0.19 | 1.49 | 2.42 | 1.34 |
| JPM | -1.62 | -0.05 | -0.34 | 0.22 | 0.62 | -0.28 | -0.55 | -0.29 | -0.94 |
| PEP | -1.62 | 0.29 | -0.36 | -1.24 | 0.13 | -0.45 | 1.77 | 3.99 | 2.64 |
| DD | -0.43 | 0.15 | 0.27 | 1.67 | 2.04 | 0.95 | -0.69 | 1.60 | 1.77 |
| DIS | -0.81 | 0.58 | 1.24 | -0.45 | 1.65 | 2.35 | 1.13 | -1.10 | -0.91 |
| HD | -0.04 | 0.17 | -0.73 | -0.76 | 1.67 | 0.77 | 1.39 | 2.28 | 1.46 |
| BA | 0.94 | 0.98 | -0.86 | -0.28 | 0.77 | 0.20 | -0.30 | -0.11 | -0.91 |
| MMM | -1.40 | -0.39 | -1.26 | -1.34 | -0.32 | -1.39 | -0.27 | -0.17 | -1.59 |
| AXP | -1.03 | -0.99 | -1.54 | -1.34 | -1.09 | -1.46 | 0.20 | 0.10 | -0.07 |
| T | -0.79 | -0.54 | -1.02 | -1.22 | 0.13 | -0.02 | 0.49 | 0.73 | 0.14 |
| MCD | 0.33 | 1.48 | 0.97 | 3.41 | 3.54 | 1.94 | 1.59 | 3.08 | 1.76 |
| SLB | -0.32 | -0.29 | -2.36 | -2.14 | -0.69 | -1.83 | -0.20 | 0.96 | -0.13 |
| TXN | -1.17 | -0.52 | -1.13 | -0.32 | 1.62 | 0.14 | 0.80 | 2.24 | 1.17 |
| DOW | 0.22 | -0.03 | -0.18 | -1.28 | -1.09 | -2.09 | -0.25 | 0.16 | -1.04 |
| ABT | -0.35 | 0.41 | -0.21 | -0.95 | 0.07 | -0.62 | -0.99 | 0.14 | -0.34 |
| CL | -2.03 | -1.76 | -2.58 | -1.45 | -0.45 | -1.74 | -0.92 | 0.54 | -0.61 |
| BAC | 0.46 | 0.03 | -0.53 | -0.72 | 2.27 | 2.23 | -1.86 | -1.84 | -1.11 |
| UTX | 0.24 | 0.71 | -0.20 | -0.12 | 0.61 | -0.09 | 0.01 | 0.81 | -0.21 |
| EMR | 0.22 | 1.26 | -0.02 | -1.26 | 0.91 | 0.22 | 0.61 | 1.38 | 1.21 |
| MDT | 0.50 | 0.78 | 0.84 | -1.13 | -0.23 | -1.32 | 0.42 | 1.84 | 0.25 |
| UNH | -1.85 | -1.62 | -2.45 | -1.83 | -0.51 | -1.71 | -1.02 | -0.22 | -1.40 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 757th to 1008th forecasting day.

Table B.35: DMW statistics of intraday volatility forecasts without overnight jump with QLIKE loss function (1009-1260)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | -0.33 | 0.11 | -0.68 | -1.29 | -0.70 | -1.12 | 0.12 | 1.09 | 0.33 |
| GE | 1.15 | 1.55 | 0.30 | 0.04 | 1.00 | 0.38 | 1.82 | 1.66 | -0.15 |
| MO | -1.74 | -1.62 | -2.01 | 1.54 | 3.37 | 0.27 | 0.09 | 0.71 | -1.64 |
| MRK | -0.19 | 0.38 | -1.27 | 0.36 | 1.76 | -0.50 | -1.29 | -1.21 | -1.35 |
| KO | 0.51 | 0.89 | 0.98 | 0.73 | 2.51 | 2.03 | -0.55 | 3.47 | 3.57 |
| PFE | -0.31 | 0.87 | 0.37 | 0.14 | 1.12 | 0.36 | -0.47 | -0.29 | -0.95 |
| JNJ | -1.19 | -0.24 | -0.52 | -1.67 | -0.12 | -0.44 | -0.11 | 1.91 | 0.59 |
| AIG | -1.22 | -0.92 | -1.63 | -0.95 | -0.55 | -0.93 | -0.27 | 2.20 | 0.23 |
| PG | 0.04 | 0.30 | -0.81 | -0.57 | 0.24 | -0.89 | -1.31 | -0.43 | -0.89 |
| WMT | -0.56 | -0.08 | -1.43 | -2.01 | -0.12 | -1.32 | -0.94 | 0.90 | -0.31 |
| JPM | -0.82 | -0.53 | -1.53 | -0.90 | 0.38 | -0.81 | 1.81 | 2.00 | 0.27 |
| PEP | 2.38 | 2.27 | 0.62 | -0.37 | 1.00 | 0.20 | 0.97 | 1.92 | 0.64 |
| DD | 0.13 | 0.27 | -2.51 | -0.76 | -0.72 | -1.99 | -1.85 | -1.27 | -2.06 |
| DIS | 2.96 | 2.77 | 0.79 | -0.12 | 0.12 | -0.22 | 1.63 | 3.22 | 0.97 |
| HD | 1.06 | 1.79 | -0.25 | -1.36 | -0.23 | -1.55 | -1.06 | -0.45 | -1.89 |
| BA | -0.62 | -0.73 | -2.22 | -0.45 | 1.12 | -0.57 | 0.28 | 0.74 | -0.33 |
| MMM | -1.33 | -0.83 | -2.01 | -0.17 | 0.65 | -1.32 | 0.54 | 0.99 | -1.01 |
| AXP | -1.48 | -1.36 | -2.09 | -2.60 | -2.17 | -3.66 | -2.05 | -2.05 | -2.99 |
| T | -1.33 | -0.81 | -2.04 | -2.20 | -1.02 | -1.87 | -1.30 | -0.05 | -1.46 |
| MCD | -2.11 | -1.65 | -2.61 | -1.37 | -0.14 | -1.42 | -1.30 | -0.93 | -1.81 |
| SLB | -2.31 | -2.00 | -3.84 | -2.59 | -2.13 | -2.87 | -3.04 | -1.57 | -2.91 |
| TXN | -0.59 | 0.84 | 0.43 | -0.86 | 0.65 | 0.42 | -0.39 | -0.69 | -1.17 |
| DOW | -1.24 | -0.28 | -2.85 | -0.36 | -0.02 | -0.30 | -0.95 | 0.04 | -1.77 |
| ABT | -2.20 | -1.10 | -1.86 | -0.94 | -0.21 | -1.41 | -0.07 | 2.05 | 0.07 |
| CL | 0.87 | 0.90 | -1.38 | -0.41 | 0.64 | -0.78 | 0.10 | 2.80 | 0.56 |
| BAC | 0.23 | 0.49 | -0.18 | -1.74 | -1.01 | -1.61 | -0.78 | -0.54 | -1.31 |
| UTX | 1.00 | 2.29 | 1.12 | -0.76 | 0.33 | -0.49 | 2.68 | 2.34 | 0.84 |
| EMR | -1.25 | -0.22 | -1.32 | -1.06 | -0.33 | -1.36 | -1.37 | -0.50 | -1.43 |
| MDT | -0.67 | 0.25 | -1.06 | 1.16 | 2.65 | 0.54 | 0.37 | 1.94 | -0.22 |
| UNH | -1.39 | -0.96 | -2.68 | -1.62 | -0.58 | -2.09 | -1.08 | -0.31 | -2.69 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 1009th to 1260th forecasting day.

Table B.36: DMW statistics of intraday volatility forecasts without overnight jump using the QLIKE loss function (1261-end)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.69 | 2.19 | 0.84 | 0.70 | 1.74 | 0.24 | -1.22 | -0.74 | -1.67 |
| GE | -1.27 | -0.16 | -0.77 | -0.45 | 1.14 | 0.39 | -1.41 | -1.12 | -2.07 |
| MO | -0.76 | 0.33 | -0.42 | 0.81 | 3.50 | 0.87 | -0.92 | -0.20 | -1.60 |
| MRK | -1.28 | -0.50 | -2.41 | -0.39 | 0.53 | -0.41 | -1.12 | 0.29 | -1.09 |
| KO | 1.22 | 1.51 | 0.66 | -0.94 | 0.49 | 0.24 | -1.41 | -0.35 | -0.43 |
| PFE | -0.53 | 0.86 | 0.81 | 0.73 | 4.23 | 3.95 | 3.15 | 2.58 | 1.02 |
| JNJ | 0.29 | 1.62 | 1.01 | 0.38 | 4.20 | 3.70 | -0.33 | 0.75 | 0.49 |
| AIG | 0.39 | 1.58 | 0.43 | 0.16 | 0.58 | -0.20 | -1.62 | -0.79 | -1.10 |
| PG | -0.92 | 0.60 | -0.05 | 0.70 | 4.56 | 3.67 | 0.25 | -0.13 | -0.87 |
| WMT | -0.08 | 0.85 | -0.84 | 1.42 | 3.24 | 1.45 | -0.36 | 0.65 | -0.60 |
| JPM | -0.87 | -0.12 | -1.55 | -1.09 | -0.37 | -1.98 | -2.32 | -2.05 | -2.59 |
| PEP | 1.04 | 0.82 | -0.55 | 1.22 | 4.32 | 2.92 | -2.14 | -0.48 | -0.79 |
| DD | 0.19 | 0.76 | -0.68 | -0.32 | 1.29 | 0.18 | -0.76 | 0.52 | -0.66 |
| DIS | -0.85 | -0.83 | -2.47 | -0.67 | 0.59 | -0.30 | -0.61 | -0.64 | -1.29 |
| HD | -0.90 | 0.99 | -0.34 | -2.59 | -1.12 | -1.46 | -0.86 | -0.43 | -1.09 |
| BA | -1.38 | -1.06 | -1.06 | -0.52 | 1.00 | 0.16 | -2.17 | -1.07 | -1.85 |
| MMM | -1.48 | -0.19 | -1.44 | -0.94 | -0.19 | -1.62 | -0.86 | 0.59 | -0.79 |
| AXP | -0.20 | 0.08 | -0.34 | -1.01 | -0.87 | -1.95 | -2.10 | -2.29 | -0.84 |
| T | -2.17 | -1.93 | -2.83 | -1.95 | -1.14 | -2.15 | -2.51 | -2.27 | -3.34 |
| MCD | -0.34 | 0.96 | -0.82 | -1.05 | 0.55 | -0.60 | -0.99 | -0.05 | -0.90 |
| SLB | 0.40 | 1.19 | -0.08 | -0.13 | 0.49 | -0.62 | -2.87 | -2.33 | -2.73 |
| TXN | -0.16 | 1.42 | 0.60 | -1.88 | -0.26 | -0.90 | -1.15 | 1.33 | 0.75 |
| DOW | -0.57 | 0.81 | -0.54 | -0.24 | 0.03 | -0.75 | -1.39 | -0.08 | -1.36 |
| ABT | -0.98 | 0.90 | -0.44 | 0.44 | 1.85 | 0.70 | -1.90 | 0.37 | -0.29 |
| CL | -1.04 | -0.14 | -1.40 | 0.00 | 3.06 | 1.04 | -1.11 | 0.45 | -0.65 |
| BAC | -1.32 | 0.49 | -0.60 | -0.21 | 1.41 | -0.13 | -2.27 | -2.05 | -2.53 |
| UTX | -0.05 | -0.55 | -1.75 | -0.30 | 2.22 | 1.97 | -3.27 | -1.64 | -1.37 |
| EMR | -1.72 | -1.21 | -2.62 | -1.23 | 0.22 | -1.16 | -2.59 | -1.94 | -3.11 |
| MDT | -1.46 | -0.82 | -1.74 | -0.43 | 1.25 | -0.14 | -1.48 | 0.59 | -0.83 |
| UNH | -1.95 | -1.54 | -2.54 | -1.66 | -0.82 | -1.82 | -0.85 | 1.40 | -0.13 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period is from the 1261th to the end forecasting days.

Table B.37: DMW statistics of intraday volatility forecasts without overnight jump using the QLIKE loss function (whole period)

| Stock | 10:00-12:00 | | | 12:00-14:00 | | | 14:00-16:00 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | | $s_i^E$ | $s_i$ | |
| | RK | RK | ICV | RK | RK | ICV | RK | RK | ICV |
| IBM | 0.47 | 2.39 | 0.75 | -1.50 | 1.85 | 1.20 | -1.47 | -0.80 | -0.01 |
| GE | -1.44 | 0.32 | -1.02 | -1.93 | 0.81 | -0.28 | -1.48 | -1.34 | -2.43 |
| MO | -2.36 | -1.71 | -2.56 | -1.36 | -0.63 | -1.64 | -1.51 | 0.61 | -1.72 |
| MRK | -2.38 | -1.84 | -3.67 | -2.00 | 0.15 | -2.53 | -2.77 | -1.73 | -2.16 |
| KO | -1.61 | -0.31 | -0.99 | -1.62 | 1.46 | 0.43 | -2.72 | -0.93 | -1.12 |
| PFE | -1.55 | 0.28 | -0.22 | -2.15 | 1.50 | 1.30 | -0.64 | 0.08 | -0.85 |
| JNJ | -1.77 | 0.26 | -0.96 | -0.98 | 3.82 | 2.40 | -1.44 | 0.03 | -0.50 |
| AIG | -2.77 | -2.54 | -2.53 | -1.94 | -1.10 | -2.07 | -3.28 | -1.81 | -2.39 |
| PG | -2.41 | 1.01 | -0.39 | -1.16 | 5.28 | 3.57 | -1.89 | -0.20 | -1.24 |
| WMT | -1.21 | 0.70 | -1.82 | -1.12 | 3.59 | 1.32 | -1.62 | -0.11 | -1.01 |
| JPM | -2.28 | -1.52 | -2.70 | -2.06 | -0.07 | -1.02 | -2.49 | -1.85 | -2.66 |
| PEP | -0.81 | 1.15 | 0.74 | 0.03 | 4.22 | 2.91 | -1.65 | 0.74 | 0.36 |
| DD | -1.68 | -0.74 | -1.75 | -1.20 | 1.62 | 0.22 | -2.47 | -0.68 | -1.56 |
| DIS | -1.03 | -0.26 | 0.34 | -0.95 | 1.46 | 1.81 | -0.53 | 0.74 | 0.68 |
| HD | -0.81 | 0.61 | -1.21 | -3.34 | 0.36 | -0.81 | -2.21 | -0.97 | -2.25 |
| BA | -1.91 | -2.05 | -1.34 | -2.00 | 1.15 | 0.53 | -2.29 | -0.17 | -0.67 |
| MMM | -3.55 | -2.03 | -3.75 | -2.58 | -0.63 | -2.06 | -2.59 | -1.18 | -3.13 |
| AXP | -2.41 | -2.20 | -2.68 | -3.35 | -0.88 | -1.85 | -3.39 | -3.24 | -2.90 |
| T | -3.61 | -2.91 | -4.60 | -3.36 | -1.30 | -2.25 | -3.00 | -2.04 | -3.46 |
| MCD | -2.98 | -1.94 | -3.05 | -1.59 | 0.47 | -1.02 | -1.65 | -0.01 | -1.13 |
| SLB | -2.79 | -2.14 | -3.70 | -3.96 | -1.29 | -2.21 | -3.99 | -1.09 | -2.19 |
| TXN | -2.80 | -1.06 | -1.78 | -2.95 | 0.77 | -0.52 | -2.24 | 0.58 | 0.13 |
| DOW | -2.34 | -1.83 | -3.24 | -1.35 | -0.77 | -1.19 | -2.83 | -1.83 | -2.94 |
| ABT | -2.40 | -1.38 | -2.82 | -1.99 | 1.48 | -0.21 | -3.15 | -0.13 | -1.04 |
| CL | -2.86 | -2.40 | -4.15 | -1.94 | 2.46 | -0.70 | -1.93 | 0.04 | -1.67 |
| BAC | -1.31 | 0.02 | -1.17 | -2.18 | 1.00 | 0.13 | -3.03 | -2.70 | -3.36 |
| UTX | -2.62 | -2.00 | -2.45 | -1.21 | -0.71 | -0.97 | -2.31 | -1.60 | -1.93 |
| EMR | -3.57 | -2.23 | -0.52 | -3.10 | -0.39 | -1.30 | -3.24 | -2.05 | -3.58 |
| MDT | -1.97 | -0.92 | -1.48 | -1.07 | 2.41 | -0.53 | -2.45 | 0.99 | -1.74 |
| UNH | -3.63 | -2.98 | -4.70 | -3.04 | 0.15 | -2.45 | -1.92 | 0.41 | -1.58 |

Note: The benchmark model is HAR-MEM (ICV) with $s_i^E$. All models use HAR-MEM as the daily component, but the input of volatility measure and the periodicity component are different. $r_{t,i}^2$ is the proxy. The test period includes whole forecasting days.