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Predicting the Daily Covariance Matrix for S&P 100 Stocks Using Intraday Data—But Which Frequency to Use?

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also robust to the presence of transaction costs and to the portfolio rebalancing frequency.

Keywords: **Bias-correction** **High-frequency data** **Mean-variance analysis** **Realized volatility**
Tracking error **Volatility timing**

JEL Classification: **G11**

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Notes

¹Zhang et al. (2005) focus solely on estimating the variance but here we apply their approach to covariances as well, as suggested by Zhang (2005).

²We should note that the two-time scale estimator of Zhang et al. (2005) is derived under the assumption of constant volatility. By using it in the same way as in the present paper, the weights for the covariances estimator may be biased. These reservations are addressed in the current paper.

³<http://www.elsevier.com/locate/jfs>

⁴For example, see the first trading strategy in the paper.

Notes: The first row of the matrix Σ is the average of various sampling frequencies from 1990 to 1997, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024. The mean reflects the average of the variance is the average of the realized

covariance the mean reflects the average taken over all 3003 pairs of stocks and over all 1788 trading days. The variance is the average taken over the 3003 sample variances of the realized covariances. In Panel A the “standard” realized covariance matrix $V_{t-1, h}$ given in (1) is used. Panel B is based on the two time-scales estimator given in (2), while Panel C shows results for the lead-lag corrected estimator given in (3), with Bartlett-kernel weights $d_l = 1 - l/(q + 1)$ and $q = 1$.

⁵An exception is the realized variance at the one- and two-minute frequencies, where also the variance increases due to the increased importance of bid-ask bounce.

⁶We experimented with alternative values for q , which led to qualitatively similar findings. Detailed results are available upon request. The issue of determining the optimal value of q is beyond the scope of this article and is left for future research.

⁷As explained below, we require part of the sample period to initialize the conditional covariance matrix estimates, which in our case equals 122 trading days. This implies that the effective sample period available for portfolio construction and evaluation runs from October 8, 1997 until May 27, 2004 (1666 trading days).

⁸Fleming et al. (2003) use a similar approach when assessing the effect of transaction costs.

⁹Note that our approach here differs from Fleming et al. (2003). Our method of holding multiple stocks in a portfolio is different from their method of holding a single stock. We also consider a larger number of stocks, and we consider many other factors.

¹⁰Fleming et al. (2003) use a GARCH model to estimate the conditional variance. Our model uses a GARCH model to estimate the conditional variance. The result in our case is similar to their result. They also use a GARCH model to estimate the conditional variance.

Notes: The first column shows the results for the standard estimator, the second column shows the results for the two time-scales estimator, and the final two columns show the results for the lead-lag corrected estimator. The first column shows the results for the standard estimator, the second column shows the results for the two time-scales estimator, and the final two columns show the results for the lead-lag corrected estimator. The first column shows the results for the standard estimator, the second column shows the results for the two time-scales estimator, and the final two columns show the results for the lead-lag corrected estimator.



columns when 1 lead and 1 lag of the (co-)variances are added to the contemporaneous (realized) covariances.

Notes: The table shows the out-of-sample performance of the overall minimum variance portfolio, with weights given in (6), and the minimum variance portfolio given a target level of return of 10%, with weights given in (8), constructed using rolling covariance matrix forecasts based on various sampling frequencies and based on different ways of measuring the realized covariance matrix (standard, two time-scales, and 1 lead and 1 lag). For the target return portfolios, we report the mean return (μ_P) and standard deviation (σ_P) in annualized percentage points, the Sharpe ratio (SR), the annualized basis points fee (Δ_γ) an investor with quadratic utility and constant relative risk aversion of γ would pay to switch from the daily returns covariance matrix estimate to the intraday returns of the optimal portfolios, and average daily turnover (TO) in percentage points. For the minimum variance portfolios, we report the standard deviation (α_{MVP}) in annualized percentage points average daily turnover (TO) in percentage points.

¹¹We examined the sensitivity of our results to the target return level by varying μ_P between 2% and 18%. These alternative target return levels led to qualitatively similar conclusions as those reported below. Detailed results are therefore not shown here, but are available on request.

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Notes: The table shows the out-of-sample performance of the minimum variance portfolio given a target level of return of 10%, with weights given in (8), constructed using rolling covariance matrix forecasts based on daily returns and on intraday returns at the sampling frequency that maximized the information ratio, based on the “standard” way of measuring the realized covariance matrix. We report the mean return (μ_p) and standard deviation (α_p) in annualized percentage points, the Sharpe ratio (SR), and the annualized basis points fee (Δ_γ) an investor with quadratic utility and constant relative risk aversion of γ would pay to switch from the daily returns covariance matrix estimate to the intraday returns of the optimal portfolios. The column headed c indicates the level of transaction costs, expressed in annualized percentage points, which correspond with the reduction in the annualized portfolio return if the entire portfolio would have to be traded every day during the whole year. The column headed h indicates the optimal sampling frequency, expressed as the length of the corresponding return interval in minutes.

Notes: The table shows the out-of-sample performance of the minimum tracking error portfolio given a target level of return of 1%, with weights given in (8), constructed using rolling covariance matrix forecasts based on daily returns and on intraday returns at the sampling frequency that maximized the information ratio, based on the ‘standard’ way of measuring the realized covariance matrix. We report the mean active return (μ_p) and tracking error (TE_p) in annualized percentage points, the information ratio (IR), and the annualized basis points fee (Δ_γ) an investor with quadratic utility and constant relative risk aversion of γ would pay to switch from the daily returns covariance matrix estimate to the intraday returns of the optimal portfolios. The column headed c indicates the level of transaction costs, expressed in annualized percentage points, which correspond with the reduction in the annualized portfolio return if the entire portfolio would have to be traded every day during the whole year. The column headed h indicates the optimal sampling frequency, expressed as the length of the corresponding return interval in minutes.



Notes: The table shows the out-of-sample performance of the minimum volatility portfolio (tracking error) given a target level of return of 1%, with weights given in (8), constructed using rolling covariance matrix forecasts based on daily returns and on intraday returns at the sampling frequency that maximized the information ratio. Table A shows results for the minimum volatility portfolio and the S&P 500 (tracking error). The optimal decay parameters are determined by optimizing portfolio

performance using an expanding window period (starting with 250 days). Columns 2 and 3, and 6 and 7, report the mean and standard deviation of the resulting estimates of α_h . Columns 4 and 8, headed 'Perf.', show the Sharpe ratio and volatility (panel A) or the information ratio and tracking error (panel (B) for the resulting portfolios. Columns 5 and 9, headed 'LogL', show the SR/IR and σ_P/TE_P for portfolios constructed with decay parameters for the conditional covariance matrix that are estimated by maximizing the log-likelihood over the complete out-of-sample period.

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