

*Supplemental Appendix for:*

Does Anything Beat 5-Minute RV?

A Comparison of Realized Measures Across Multiple Asset Classes

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**S.A.1 Data Cleaning**

All series were cleaned according to a set of baseline rules similar to those in Barndorff-Nielsen et al. (2009).

Using notation from that paper, these rules are:

P1 Prices out of normal business hours were discarded.

P2 Prices with a 1-tick reversal greater than 15 times the median spread were removed.

P3 Prices were aggregated using the median of all prices with that time stamp.

Q1 Quotes with bid above offer were removed.

Q2 Quotes with a spread greater than 15 times the daily median spread were removed

QT1 The maximum price was determined as the minimum of the maximum offer and the maximum transaction price, plus 2 times the daily median standard deviation. The minimum price was determined as the maximum of the minimum bid and the minimum transaction price, minus 2 times the daily spread. Transactions with prices outside of this range, or quotes where either price was outside this range were removed.

QT2 Transactions with prices that were outside of the lowest bid highest and offer over the previous 1 minute and subsequent 1 minute were removed. No action was taken if there were no quotes during this period.

QT3 Quotes with bids above or offers below the observed trading price range over the previous and subsequent minute were removed.

F1 The active future was chosen according to the highest transaction volume on each trading day, with the condition that once a future has been selected, it cannot be deselected in favor of a new contract and then reselected. To avoid this, a unique roll date was selected by maximizing the total transaction volume to choose a single roll date.

On the rare occasion that a problem was detected, the problematic data points were removed manually. Manual cleaning was needed in less than 0.1% of all days.

## **S.A.2 Additional Summary Statistics and Results**

This section summarizes some further summary statistics for the realized measures.

Our broad implementation of realized measures means that some questionable estimators are included, and for some of these measures, we see unrealistic estimates of QV (negative or zero values, for example) for several days. We use the following simple rule to remove the worst estimators before proceeding to formal rankings and tests: if values of the realized measure are less than a prespecified cutoff (0.0001 for interest rate and currency futures or 0.001 for all other assets) for more than 5% of the days in the sample, then that estimator is removed from the competing set, and not included in any subsequent analysis. Only 12 of the 31 assets have any realized measures removed, and the maximum number of removed measures is seven (out of 420 measures in total). Realized measures with a small number of unrealistic estimates are retained, and the values below the cutoff are replaced with the previous day's value. Table A2 records the estimators that are removed from each competing set for each asset according to this rule. Not surprisingly, these estimators include many that were implemented on an inappropriate sampling frequency relative to the frequency of the available price data.

Tables A3 and A4 supplement Table 2, providing summary statistics for each individual asset.

Table A5 presents information on the correlation between the estimators. As one would expect, the majority of the remaining estimators are highly correlated. On average, about half of the correlations are over 0.9, and about 25% are 0.95 or higher.

Table A6 presents correlation matrices for the ranks of individual realized measures, according to estimated accuracy, across pairs of assets in a given asset class. These rank correlations provide insights into whether the relative performance of realized measures is similar across assets in the same asset class.

Table A7 lists the size of the estimated model confidence set (MCS) for each individual asset.

Results from some robustness checks are presented in Table A8. We conduct Romano-Wolf tests substituting MSE loss for QLIKE loss, or replacing the random-walk approximation for QV with an AR(1) or AR(5) approximation. Consistent with expectations, we find similar results to our base case but with lower power: we find no cases where RV5min is significantly beaten by an alternative, and the number of cases where RV5min is identified as significantly better than an alternative drops.

Also in Table A8, we present results from Romano-Wolf tests using two alternative QV proxies, which are the 1-day lag of RVdaily or the average of 1-day lead and 1-day lag of RVdaily. The results are very similar to using 1-day lead of RVdaily.

Tables A9 and A10 present some summary statistics and cross-correlation estimates for the conditioning variables used in the panel regressions of Section 5.5.

**Table A1**

Short-hand codes for estimators.

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**Order:** Class - SamplingFreq - SamplingScheme PriceSeries - Subsampling
**Classes of Realized Measures**

RV	Realized Variance
RVss	Subsampled Realized Variance
RVpa	Pre-averaged Realized Variance
RVac1	First-order autocorrelation adjusted realized variance
RKbart	Realized Kernel with flat-top Bartlett kernel
RKcub	Realized Kernel with flat-top cubic kernel
RKth2	Realized Kernel with flat-top Tukey-Hanning2 kernel
RKnpf	Realized Kernel with non-flat-top Parzen kernel
TSRV	Two-scales realized variance
MSRV	Multi-scales realized variance
MLRV	Maximum-Likelihood realized variance
RRVm5	Realized range-based variance with block length 5
RRVm10	Realized range-based variance with block length 10
BR	Realized Variance with Bandi-Russell Optimal Sampling

*jump-robust estimators:*

BPV	Bipower Realized Variance
BPVpa	Pre-averaged Bipower Variance
minRV	MinRV
medRV	MedRV
QRV	Quantile Realized Variance
TrunRV	Truncated (Threshold) Realized Variance

**Sampling Frequency**

1t	tick-by-tick
1s	1-second
5s	5-second
1m	1-minute
5m	5-minute
15m	15-minute

**Sampling Scheme**

c	calendar-time sampling
b	tick (business)-time sampling

**Price series**

t	transactions prices
q	midquote

**Subsampling**

ss	subsampled
“blank”	not subsampled

**Example:**

RV_1m_ct_ss	Realized variance, using 1-minute calendar time sampling of trade prices, sub-sampled
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**Table A2**

Non-jump robust estimators that were not implemented due to having a large number of very small or negative values

KO	MSRV_15m_ct	MSRV_15m_cq						
LSI	MSRV_15m_ct	MSRV_15m_cq	MSRV_15m_bq					
MSFT	MSRV_15m_ct	MSRV_15m_cq						
IFF	MSRV_15m_ct	MSRV_15m_bt	MSRV_15m_cq	MSRV_15m_bq	MSRV_15m_ct_ss	MSRV_15m_cq_ss	MSRV_15m_bq_ss	
SYF	MSRV_15m_ct	MSRV_15m_bt	MSRV_15m_cq	MSRV_15m_bq	MSRV_15m_ct_ss	MSRV_15m_cq_ss		
VOD	BRbc_cq							
SDR	TSRV_15m_bt	MSRV_15m_ct	MSRV_15m_bt	MSRV_15m_ct_ss				
RSA	MSRV_15m_ct							
TU	MSRV_15m_cq							
US	RVac1_1t_bt							
JNI	BRbc_cq	BRbc_bq	BRbc_cq_ss	BRbc_bq_ss				
N225	MSRV_15m_c	MSRV_15m_b						

*Notes:* This table lists the estimators that are removed from the competing set before proceeding to formal rankings and tests (i.e., not implemented). These estimators are identified using the following rule: more than 5% of the sample days yield estimated values that are less than a prespecified cutoff (0.0001 for interest rate and currency futures or 0.001 for all other assets).

**Table A3**

Summary of Sample Means and Standard Deviations of Realized Measures

	Sample Mean				Sample Standard Deviation			
	median	std dev	min	max	median	std dev	min	max
<b>KO</b>	1.77	1.82	0.32	17.24	2.82	2.46	0.96	23.00
<b>LSI</b>	11.46	10.73	1.07	106.98	14.64	11.94	3.12	115.60
<b>MSFT</b>	3.08	3.78	0.84	31.34	4.19	5.14	1.59	37.90
<b>IFF</b>	2.75	2.21	0.24	21.72	5.17	3.37	0.56	30.66
<b>SYF</b>	2.37	2.72	0.41	24.49	3.50	4.27	0.65	37.56
<b>DGE</b>	2.68	3.38	0.60	31.37	4.06	5.29	1.43	42.47
<b>VOD</b>	4.37	9.23	1.38	68.50	5.64	10.20	2.28	70.50
<b>SAB</b>	3.54	2.55	1.21	22.40	6.19	4.38	1.83	29.24
<b>SDR</b>	8.70	6.09	0.89	47.60	17.01	10.36	1.67	70.39
<b>RSA</b>	6.93	6.88	1.03	61.13	11.82	9.06	2.71	81.44
<b>TU</b>	0.01	0.01	0.00	0.09	0.02	0.01	0.01	0.11
<b>FV</b>	0.06	0.06	0.03	0.53	0.08	0.05	0.03	0.56
<b>TY</b>	0.13	0.15	0.06	1.18	0.17	0.12	0.06	1.20
<b>US</b>	0.32	0.39	0.14	3.22	0.39	0.29	0.13	2.73
<b>FGBL</b>	0.09	0.11	0.03	0.95	0.08	0.08	0.03	0.73
<b>FGBS</b>	0.01	0.02	0.00	0.09	0.02	0.72	0.01	2.47
<b>CD</b>	0.33	0.37	0.15	3.17	0.35	0.37	0.16	3.12
<b>AD</b>	0.50	0.56	0.19	4.74	1.00	1.06	0.39	8.72
<b>BP</b>	0.23	0.26	0.10	2.15	0.30	0.34	0.14	2.72
<b>URO</b>	0.24	0.27	0.11	2.30	0.26	0.28	0.10	2.25
<b>JY</b>	0.28	0.30	0.12	2.56	0.36	0.34	0.16	2.88
<b>STXE</b>	1.76	2.06	0.57	16.58	3.17	3.97	1.38	29.25
<b>JNI</b>	1.15	1.73	0.42	14.03	1.72	1.84	0.55	15.03
<b>FDX</b>	1.75	1.96	0.63	16.54	2.81	2.92	1.31	23.97
<b>FFI</b>	1.29	1.51	0.61	12.31	2.10	2.45	0.96	19.06
<b>ES</b>	1.26	1.93	0.58	14.64	2.65	3.43	1.17	24.14
<b>SPX</b>	1.11	1.13	0.04	10.49	2.51	2.15	0.10	20.52
<b>STOXX50E</b>	1.51	1.47	0.08	13.63	2.53	2.20	0.17	20.02
<b>DAX</b>	1.78	1.81	0.35	16.45	3.05	2.78	1.04	24.47
<b>FTSE</b>	1.04	1.00	0.05	9.46	2.08	1.55	0.12	14.45
<b>N225</b>	0.91	0.66	0.02	7.67	1.44	1.13	0.04	12.51

*Notes:* The sample mean and standard deviation of each of the implemented realized measures for all 31 assets are calculated. This table summarizes the summary statistics by listing the median sample mean, the standard deviation of the sample means, and the minimum and maximum values of sample means for a given asset. We do the same for the collection of approximately 648 (or 324) sample standard deviations for each asset.

**Table A4**

Estimated autocorrelation of realized measures and quadratic variation

	<b>ac(1)</b>			<b>ac(2)</b>			<b>ac*(1)</b>			<b>ac*(2)</b>		
	mean	std dev	RV5m	mean	std dev	RV5m	mean	std dev	RV5m	mean	std dev	RV5m
<b>KO</b>	0.61	0.11	0.62	0.61	0.10	0.61	0.93	0.03	0.95	0.90	0.03	0.94
<b>LSI</b>	0.59	0.10	0.64	0.53	0.11	0.60	0.94	0.07	0.98	0.90	0.11	0.96
<b>MSFT</b>	0.73	0.11	0.72	0.70	0.11	0.68	0.96	0.02	0.96	0.94	0.02	0.95
<b>IFF</b>	0.48	0.14	0.46	0.45	0.15	0.41	0.95	0.01	0.93	0.92	0.02	0.93
<b>SYY</b>	0.56	0.08	0.57	0.52	0.11	0.53	0.91	0.03	0.91	0.88	0.04	0.90
<b>DGE</b>	0.60	0.11	0.61	0.54	0.11	0.49	0.97	0.02	0.98	0.95	0.02	0.97
<b>VOD</b>	0.67	0.11	0.45	0.60	0.12	0.44	0.97	0.01	0.96	0.95	0.02	0.95
<b>SAB</b>	0.50	0.12	0.49	0.41	0.12	0.33	0.96	0.03	0.97	0.94	0.04	0.91
<b>SDR</b>	0.48	0.11	0.59	0.38	0.09	0.48	0.93	0.03	0.95	0.91	0.04	0.94
<b>RSA</b>	0.56	0.11	0.56	0.52	0.10	0.50	0.97	0.02	0.96	0.95	0.01	0.93
<b>TU</b>	0.37	0.16	0.35	0.37	0.14	0.35	0.96	0.03	0.94	0.95	0.02	0.95
<b>FV</b>	0.25	0.15	0.20	0.23	0.13	0.17	0.96	0.02	0.95	0.94	0.02	0.94
<b>TY</b>	0.30	0.18	0.19	0.27	0.16	0.16	0.97	0.02	0.96	0.94	0.02	0.94
<b>US</b>	0.27	0.17	0.17	0.24	0.15	0.13	0.96	0.02	0.94	0.93	0.03	0.92
<b>FGBL</b>	0.55	0.15	0.60	0.48	0.13	0.52	0.97	0.01	0.96	0.93	0.01	0.91
<b>FGBS</b>	0.29	0.30	0.58	0.25	0.25	0.49	0.92	0.16	0.96	0.82	0.28	0.94
<b>CD</b>	0.70	0.11	0.68	0.67	0.10	0.68	1.00	0.02	1.00	0.98	0.01	0.97
<b>AD</b>	0.73	0.08	0.71	0.76	0.05	0.78	0.93	0.05	0.94	0.90	0.04	0.93
<b>BP</b>	0.75	0.10	0.71	0.72	0.08	0.70	0.99	0.01	0.99	0.98	0.01	0.98
<b>URO</b>	0.64	0.12	0.63	0.60	0.12	0.58	0.98	0.01	0.98	0.96	0.01	0.95
<b>JY</b>	0.54	0.13	0.50	0.44	0.12	0.40	0.95	0.01	0.95	0.91	0.02	0.93
<b>STXE</b>	0.46	0.25	0.61	0.41	0.23	0.54	0.95	0.02	0.95	0.94	0.02	0.94
<b>JNI</b>	0.70	0.11	0.70	0.66	0.10	0.63	0.91	0.05	0.86	0.92	0.04	0.87
<b>FDX</b>	0.64	0.15	0.23	0.58	0.14	0.20	0.95	0.01	0.96	0.95	0.02	0.95
<b>FFI</b>	0.72	0.09	0.71	0.69	0.07	0.65	0.95	0.02	0.97	0.94	0.01	0.94
<b>ES</b>	0.67	0.09	0.68	0.66	0.09	0.67	0.90	0.03	0.87	0.86	0.04	0.85
<b>SPX</b>	0.66	0.08	0.69	0.65	0.08	0.68	0.91	0.03	0.92	0.86	0.03	0.86
<b>STOXX50E</b>	0.67	0.09	0.57	0.63	0.07	0.57	0.94	0.03	0.90	0.93	0.03	0.89
<b>DAX</b>	0.69	0.08	0.70	0.59	0.08	0.62	0.94	0.01	0.96	0.94	0.02	0.96
<b>FTSE</b>	0.54	0.10	0.55	0.53	0.09	0.51	0.90	0.05	0.89	0.88	0.06	0.85
<b>N225</b>	0.70	0.10	0.74	0.64	0.08	0.67	0.95	0.04	0.95	0.94	0.03	0.94
<b>Average</b>	0.57	0.12	0.56	0.53	0.12	0.51	0.95	0.03	0.95	0.92	0.04	0.93

*Notes:* This table lists the mean and standard deviation, by asset, of sample autocorrelations of realized measures (denoted “ac”) and the estimated autocorrelation of QV based on a realized measure (denoted “ac\*”), using the instrumental variables method of Hansen and Lunde (2010). The autocorrelation estimates for RV5min (with calendar-time sampling of transaction prices) are also presented.

**Table A5**

Quantiles of pairwise correlations between realized measures of a given asset

	<b>0.01</b>	<b>0.05</b>	<b>0.1</b>	<b>0.25</b>	<b>0.5</b>	<b>0.75</b>	<b>0.9</b>	<b>0.95</b>	<b>0.99</b>
<b>KO</b>	0.51	0.63	0.68	0.76	0.85	0.92	0.96	0.98	0.99
<b>LSI</b>	0.36	0.48	0.57	0.70	0.82	0.91	0.96	0.97	0.99
<b>MSFT</b>	0.32	0.51	0.63	0.76	0.87	0.94	0.98	0.99	1.00
<b>IFF</b>	0.44	0.52	0.60	0.70	0.85	0.95	0.98	0.99	1.00
<b>SYX</b>	0.43	0.60	0.66	0.78	0.88	0.94	0.97	0.98	0.99
<b>DGE</b>	0.47	0.59	0.65	0.72	0.82	0.90	0.94	0.96	0.99
<b>VOD</b>	0.39	0.65	0.70	0.78	0.87	0.93	0.96	0.97	0.99
<b>SAB</b>	0.23	0.39	0.49	0.63	0.73	0.82	0.89	0.93	0.98
<b>SDR</b>	0.21	0.38	0.47	0.61	0.72	0.81	0.89	0.94	0.99
<b>RSA</b>	0.54	0.64	0.70	0.78	0.84	0.90	0.94	0.96	0.99
<b>TU</b>	0.49	0.58	0.63	0.72	0.81	0.89	0.94	0.96	0.98
<b>FV</b>	0.39	0.51	0.56	0.66	0.76	0.86	0.92	0.95	0.98
<b>TY</b>	0.40	0.51	0.58	0.71	0.83	0.91	0.95	0.97	0.99
<b>US</b>	0.31	0.43	0.51	0.65	0.80	0.91	0.96	0.97	0.99
<b>FGBL</b>	0.43	0.56	0.62	0.72	0.83	0.91	0.95	0.97	0.99
<b>FGBS</b>	0.00	0.02	0.03	0.06	0.63	0.95	1.00	1.00	1.00
<b>CD</b>	0.60	0.79	0.82	0.88	0.93	0.96	0.98	0.99	0.99
<b>AD</b>	0.68	0.84	0.88	0.92	0.96	0.98	0.99	0.99	1.00
<b>BP</b>	0.74	0.82	0.85	0.90	0.94	0.97	0.99	0.99	1.00
<b>URO</b>	0.64	0.74	0.78	0.86	0.91	0.96	0.98	0.99	0.99
<b>JY</b>	0.66	0.77	0.81	0.87	0.92	0.96	0.98	0.99	0.99
<b>STXE</b>	0.16	0.23	0.28	0.47	0.79	0.94	0.98	0.99	1.00
<b>JNI</b>	0.39	0.62	0.70	0.81	0.88	0.94	0.96	0.98	0.99
<b>FDX</b>	0.45	0.57	0.66	0.80	0.90	0.95	0.98	0.99	1.00
<b>FFI</b>	0.80	0.87	0.90	0.93	0.96	0.98	0.99	0.99	1.00
<b>ES</b>	0.73	0.83	0.87	0.92	0.96	0.98	0.99	1.00	1.00
<b>SPX</b>	0.68	0.80	0.84	0.89	0.93	0.97	0.99	0.99	1.00
<b>STOXX50E</b>	0.65	0.76	0.81	0.87	0.92	0.96	0.98	0.99	1.00
<b>DAX</b>	0.57	0.72	0.79	0.87	0.92	0.96	0.98	0.99	1.00
<b>FTSE</b>	0.47	0.66	0.73	0.80	0.88	0.94	0.98	0.99	1.00
<b>N225</b>	0.59	0.69	0.75	0.86	0.93	0.97	0.99	1.00	1.00
<b>Average</b>	0.48	0.60	0.66	0.75	0.86	0.93	0.96	0.98	0.99

Notes: All values of “1.00” are due to rounding. All estimated correlations are less than 1.

**Table A6**

Cross-asset correlations of rankings

<i>Individual Equities</i>										
	<b>LSI</b>	<b>MSFT</b>	<b>IFF</b>	<b>SYY</b>	<b>DGE</b>	<b>VOD</b>	<b>SAB</b>	<b>SDR</b>	<b>RSA</b>	
<b>KO</b>	0.91	0.88	0.77	0.87	0.65	0.69	0.79	0.67	0.68	
<b>LSI</b>		0.85	0.88	0.95	0.50	0.52	0.78	0.64	0.53	
<b>MSFT</b>			0.78	0.80	0.60	0.66	0.71	0.60	0.61	
<b>IFF</b>				0.87	0.36	0.40	0.63	0.51	0.42	
<b>SYY</b>					0.44	0.42	0.74	0.65	0.49	
<b>DGE</b>						0.89	0.77	0.78	0.95	
<b>VOD</b>							0.66	0.62	0.87	
<b>SAB</b>								0.90	0.78	
<b>SDR</b>									0.85	
Avg Corr: 0.70										
<i>Currency Futures</i>					<i>Index Futures</i>					
	<b>AD</b>	<b>BP</b>	<b>URO</b>	<b>JY</b>		<b>JNI</b>	<b>FDX</b>	<b>FFI</b>	<b>ES</b>	
<b>CD</b>	0.94	0.84	0.84	0.99	<b>STXE</b>	0.88	0.65	0.66	0.89	
<b>AD</b>		0.83	0.77	0.86	<b>JNI</b>		0.52	0.51	0.77	
<b>BP</b>			0.87	0.88	<b>FDX</b>			0.96	0.81	
<b>URO</b>				0.96	<b>FFI</b>				0.80	
Avg Corr: 0.87					Avg Corr: 0.74					
<i>Bond Futures</i>						<i>Computed Indices</i>				
	<b>FV</b>	<b>TY</b>	<b>US</b>	<b>FGBL</b>	<b>FGBS</b>		<b>STX50E</b>	<b>DAX</b>	<b>FTSE</b>	<b>N225</b>
<b>TU</b>	0.96	0.90	0.87	0.83	0.70	<b>SPX</b>	0.97	0.79	0.94	0.74
<b>FV</b>		0.96	0.91	0.88	0.64	<b>STX50E</b>		0.80	0.96	0.76
<b>TY</b>			0.91	0.93	0.60	<b>DAX</b>			0.83	0.84
<b>US</b>				0.96	0.80	<b>FTSE</b>				0.70
<b>FGBL</b>					0.76	Avg Corr: 0.83				
Avg Corr: 0.84										

*Notes:* This table displays rank correlations of the rankings (based on QLIKE loss function, and taking RVdaily as the QV proxy) across assets of the same class.



**Table A7**

Size of 90% Model Confidence Sets

Asset	Total # Estimators	QV Proxy									
		<i>RVdaily</i>		<i>15min RV</i>		<i>5min RV</i>		<i>1min MSRV</i>		<i>1min RKth2</i>	
		(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
KO	418	119	28.5	8	1.9	11	2.6	9	2.2	8	1.9
LSI	417	32	7.7	11	2.6	10	2.4	4	1.0	10	2.4
MSFT	418	79	18.9	6	1.4	3	0.7	5	1.2	5	1.2
IFF	413	130	31.5	33	8.0	25	6.1	50	12.1	50	12.1
SYF	414	148	35.7	13	3.1	20	4.8	8	1.9	10	2.4
DGE	420	39	9.3	14	3.3	2	0.5	15	3.6	14	3.3
VOD	419	47	11.2	6	1.4	5	1.2	4	1.0	4	1.0
SAB	420	76	18.1	18	4.3	9	2.1	1	0.2	6	1.4
SDR	416	24	5.8	3	0.7	1	0.2	3	0.7	4	1.0
RSA	419	22	5.3	6.0	1.4	9	2.1	18	4.3	13	3.1
TU	419	10	2.4	27	6.4	16	3.8	30	7.2	31	7.4
FV	420	37	8.8	5	1.2	6	1.4	4	1.0	4	1.0
TY	420	20	4.8	25	6.0	22	5.2	24	5.7	23	5.5
US	419	8	1.9	15	3.6	6	1.4	17	4.1	10	2.4
FGBL	420	3	0.7	5	1.2	4	1.0	13	3.1	10	2.4
FGBS	420	39	9.3	10	2.4	2	0.5	21	5.0	15	3.6
CD	420	33	7.9	10	2.4	6	1.4	6	1.4	4	1.0
AD	420	135	32.1	6	1.4	5	1.2	5	1.2	9	2.1
BP	420	13	3.1	20	4.8	23	5.5	9	2.1	9	2.1
URO	420	9	2.1	13	3.1	6	1.4	6	1.4	6	1.4
JY	420	18	4.3	16	3.8	11	2.6	16	3.8	16	3.8
STXE	420	15	3.6	12	2.9	10	2.4	4	1.0	10	2.4
JNI	416	15	3.6	1	0.2	2	0.5	1	0.2	1	0.2
FDX	420	18	4.3	10	2.4	4	1.0	6	1.4	5	1.2
FFI	420	19	4.5	7	1.7	18	4.3	17	4.0	20	4.8
ES	420	34	8.1	8	1.9	13	3.1	8	1.9	1	0.2
SPX	210	2	1.0	2	1.0	2	1.0	11	5.2	2	1.0
STOXX50E	210	15	7.1	5	2.4	1	0.5	8	3.8	10	4.8
DAX	210	20	9.5	1	0.5	2	1.0	11	5.2	7	3.3
FTSE	210	17	8.1	13	6.2	13	6.2	11	5.2	11	5.2
N225	208	22	10.6	6	2.9	2	1.0	5	2.4	2	1.0

Notes: Columns (a) and (b) display the number and percentage of estimators included in a 90% Model Confidence Set.

**Table A8**

Romano-Wolf Robustness Checks: Number of Realized Measures Significantly Worse than or Better than RV5min

<i>Loss function:</i> <i>QV approx:</i> <i>QV proxy:</i>	QLIKE R. Walk		MSE R. Walk		QLIKE AR(1)		QLIKE AR(5)		QLIKE R. Walk		QLIKE R. Walk Avg of 1-day lead & lag		No. RM
	1-day lead		1-day lead		1-day lead		1-day lead		1-day lag				
	<i>worse</i>	<i>better</i>	<i>worse</i>	<i>better</i>	<i>worse</i>	<i>better</i>	<i>worse</i>	<i>better</i>	<i>worse</i>	<i>better</i>	<i>worse</i>	<i>better</i>	
KO	194	0	0	0	35	0	0	0	202	0	207	0	418
LSI	183	0	53	0	97	0	0	0	262	0	237	0	417
MSFT	284	0	39	0	11	0	0	0	229	0	279	0	418
IFF	148	0	0	0	0	0	29	0	124	0	150	0	413
SYX	155	0	0	0	0	0	0	0	100	0	164	0	414
DGE	184	0	0	0	65	0	0	0	162	0	179	0	420
VOD	219	0	0	0	133	0	34	0	196	0	206	0	419
SAB	146	0	0	0	0	0	0	0	199	0	180	0	420
SDR	142	0	0	0	39	0	0	0	147	0	144	0	416
RSA	162	0	0	0	82	0	0	0	138	0	153	0	419
TU	246	0	17	0	0	0	1	0	221	0	248	0	419
FV	231	0	14	0	0	0	0	0	202	0	249	0	420
TY	224	0	3	0	3	0	0	0	221	0	234	14	420
US	245	0	0	0	13	0	3	0	251	0	253	0	419
FGBL	220	0	61	0	44	0	0	0	265	0	251	0	420
FGBS	372	0	252	0	63	0	42	0	376	0	367	0	420
CD	141	0	12	0	35	0	0	0	160	0	161	0	420
AD	126	0	0	0	0	0	0	0	143	0	183	0	420
BP	161	0	0	0	33	0	0	0	183	0	180	0	420
URO	177	0	58	0	3	0	0	0	160	0	173	0	420
JY	163	0	0	0	0	0	0	0	137	0	162	0	420
STXE	211	0	164	0	32	0	0	0	241	0	261	0	420
JNI	296	0	45	0	89	0	0	0	252	0	311	0	416
FDX	169	0	0	0	42	0	0	0	186	0	180	0	420
FFI	175	0	58	0	11	0	0	0	235	0	202	0	420
ES	186	0	8	0	8	0	0	0	223	0	209	0	420
SPX	182	0	145	0	128	0	0	0	172	0	182	0	210
STOXX50E	144	0	0	0	177	0	0	0	171	0	168	0	210
DAX	145	0	3	0	141	0	2	0	141	0	152	0	210
FTSE	184	0	0	0	170	0	0	0	170	0	188	0	210
N225	168	0	0	0	141	0	185	0	153	0	168	0	208

*Notes:* This table presents the number of realized measures that are significantly better or worse than the benchmark 5-minute RV (calendar-time sampling of transaction prices) based on five sets of Romano-Wolf tests. The base case uses qlike loss, random walk approximation for QV, and 1-day lead of RVdaily as the QV proxy. The other variations use MSE loss, an AR(1) or AR(5) approximation for QV, and lagged RVdaily or the average of 1-day lagged and 1-day lead RVdaily as the QV proxy.

**Table A9**

Mean (before demeaning) and standard deviation of conditioning variables for panel regressions

	avgdur(detr)		volm(detr)		BAsprd(detr)		ac1_5s		propjump		noiseratio		logQV	
	m	sd	m	sd	m	sd	m	sd	m	sd	m	sd	m	sd
<b>KO</b>	1.00	0.23	1.00	0.40	0.98	0.15	-0.05	0.06	0.09	0.10	0.40	0.29	0.16	0.91
<b>LSI</b>	1.01	0.29	0.98	0.57	1.00	0.29	-0.05	0.05	0.12	0.11	0.52	0.48	2.10	0.86
<b>MSFT</b>	1.03	0.30	0.98	0.43	1.00	0.15	-0.13	0.15	0.07	0.08	1.71	2.22	0.68	0.96
<b>IFF</b>	1.00	0.31	1.00	0.51	0.98	0.22	-0.01	0.03	0.12	0.13	0.24	0.20	0.66	0.87
<b>SYY</b>	1.00	0.27	1.00	0.40	0.98	0.17	-0.03	0.04	0.10	0.11	0.31	0.22	0.55	0.84
<b>DGE</b>	1.00	0.28	1.01	0.93	0.99	0.15	-0.06	0.03	0.12	0.11	1.14	0.85	0.81	0.82
<b>VOD</b>	1.00	0.28	0.99	0.84	0.98	0.12	-0.14	0.06	0.10	0.09	4.68	3.99	1.28	0.79
<b>SAB</b>	0.97	0.35	1.08	1.68	0.97	0.22	-0.03	0.04	0.18	0.18	0.65	0.75	1.07	0.91
<b>SDR</b>	0.99	0.41	1.04	1.13	0.98	0.33	-0.01	0.03	0.19	0.17	0.88	1.74	1.99	1.19
<b>RSA</b>	1.00	0.34	1.01	1.07	0.99	0.23	-0.04	0.03	0.16	0.13	1.59	1.75	1.84	0.95
<b>TU</b>	0.95	0.35	1.07	0.88	0.98	0.09	-0.07	0.05	0.22	0.17	1.02	0.94	-4.97	0.88
<b>FV</b>	0.97	0.34	1.01	0.70	0.98	0.06	-0.11	0.04	0.12	0.13	1.11	0.81	-3.09	0.79
<b>TY</b>	0.98	0.33	0.99	0.62	1.00	0.03	-0.18	0.05	0.09	0.10	2.02	1.05	-2.34	0.79
<b>US</b>	0.99	0.31	0.99	0.62	1.00	0.08	-0.18	0.05	0.09	0.10	2.86	1.94	-1.38	0.70
<b>FGBL</b>	0.99	0.32	1.02	0.58	1.00	0.02	-0.18	0.04	0.07	0.07	1.49	0.70	-2.56	0.64
<b>FGBS</b>	0.99	0.35	1.04	0.79	0.99	0.05	-0.12	0.03	0.20	0.13	2.51	1.65	-4.93	0.73
<b>CD</b>	0.98	0.31	1.04	0.31	0.99	0.11	-0.09	0.05	0.05	0.06	0.46	0.26	-1.39	0.72
<b>AD</b>	0.97	0.37	1.05	0.37	0.99	0.16	-0.05	0.04	0.05	0.06	0.29	0.15	-1.24	0.91
<b>BP</b>	0.98	0.32	1.04	0.34	0.99	0.13	-0.05	0.05	0.05	0.06	0.28	0.15	-1.87	0.81
<b>URO</b>	0.99	0.34	1.03	0.34	1.00	0.07	-0.11	0.05	0.04	0.06	0.95	0.42	-1.77	0.78
<b>JY</b>	0.98	0.38	1.06	0.88	0.99	0.07	-0.07	0.05	0.05	0.06	0.53	0.28	-1.64	0.77
<b>STXE</b>	0.99	0.29	1.04	0.41	1.00	0.08	-0.19	0.07	0.06	0.07	1.82	1.18	0.03	0.97
<b>JNI</b>	1.00	0.29	1.01	0.31	1.01	0.07	-0.22	0.06	0.13	0.13	4.26	2.32	-0.07	0.69
<b>FDX</b>	0.99	0.29	1.02	0.45	1.00	0.14	-0.08	0.04	0.05	0.06	0.52	0.30	0.01	1.01
<b>FFI</b>	0.99	0.32	1.02	0.46	0.99	0.12	-0.07	0.04	0.04	0.06	0.39	0.16	-0.29	1.00
<b>ES</b>	1.00	0.37	1.03	0.30	1.00	0.07	-0.20	0.10	0.04	0.06	4.49	2.24	-0.36	0.97
<b>SPX</b>	1.00	0.02					0.00	0.00	0.19	0.16	0.37	0.06	-0.41	1.00
<b>STOXX50E</b>	1.00	0.01					0.00	0.00	0.17	0.16	0.38	0.12	-0.08	1.02
<b>DAX</b>	0.98	0.13					0.05	0.07	0.14	0.14	0.39	0.12	0.09	1.03
<b>FTSE</b>	0.98	0.14					0.03	0.09	0.17	0.16	0.36	0.21	-0.47	1.01
<b>N225</b>	0.99	0.09					0.00	0.00	0.16	0.14	0.37	0.13	-0.33	0.81
average	0.99	0.28	1.02	0.63	0.99	0.13	-0.08	0.05	0.11	0.11	1.26	0.89	-0.58	0.87

*Notes:* This table presents sample means (before demeaning for the panel regression) and standard deviations of the winsorized (top and bottom 0.005) conditioning variables used in the panel regressions in Section 5.5, per asset. Avgdur (average duration), volm (trade volume), and BAsprd (bid-ask spread) are detrended by dividing by the mean of the past 60 days' values. Propjump (proportion of QV attributable to jumps), noiseratio (per trade ratio of noise variance to QV), and logQV (volatility measure, using subsampled 5-minute RV as QV measure) are not detrended in any way. Before entering the panel regression, all conditioning variables are de-meanned using the full sample averages that appear in this table. Regression results are available in Table 8.

**Table A10**

Cross-correlations of conditioning variables, averaged over all 31 assets

	avgdur(detr)	volm(detr)	BAsprd(detr)	ac1_5s	propjump	noiseratio	logQV
avgdur(detr)	1	-0.66	-0.03	0.01	0.07	0.06	-0.32
volm(detr)		1	-0.02	-0.02	-0.04	-0.03	0.29
BAsprd(detr)			1	0.05	-0.03	-0.05	0.29
ac1_5s				1	0.00	-0.33	0.22
propjump					1	0.13	-0.07
noiseratio						1	-0.25
logQV							1

*Notes:* This table presents average cross-correlations (averaged over values from all 31 assets) between the win-sorized (top and bottom 0.005) conditioning variables used in the panel regressions in Section 5.5, per asset. Avgdur (average duration), volm (trade volume), and BAsprd (bid-ask spread) are detrended by dividing by the mean of the past 60 days' values. Propjump (proportion of QV attributable to jumps), noiseratio (per trade ratio of noise variance to QV), and logQV (volatility measure, using subsampled 5-minute RV as QV measure) are not detrended. Regression results are available in Table 8.

**Table A11**

Conditional Relative Performance of Realized Measures and RV5min (All 31 Assets)

<i>RV5m vs.</i>	<b>RVdaily</b>	<b>RV 1m</b>	<b>MSRV 5s</b>	<b>RVac1 1m</b>	<b>RKth2 5s</b>	<b>MLRV 1s</b>
avgdur	-0.10	0.67	-0.59	-2.60	-1.80	1.74
ac1_5s	-0.07	-2.65	0.42	-1.37	0.96	-0.44
jumpprop	0.63	1.11	1.32	-0.15	2.05	-0.54
noiseratio	4.25	-8.40	-4.64	-2.78	-1.72	-14.04
logQV	-5.99	-4.32	-5.49	1.41	-3.32	-2.40
equities	-13.35	-3.53	-4.04	0.49	3.50	-17.10
bond fut	-11.51	7.15	6.22	-4.88	5.23	-2.32
FX fut	-9.25	5.22	-0.86	1.85	5.30	-2.63
index fut	-9.72	9.13	2.05	-0.06	6.12	-4.27
comp. ind.	-12.12	-1.79	-9.23	4.27	-3.67	-9.02
UK	-0.42	-15.78	-5.28	-3.65	-6.49	-11.47
Europe	1.45	-6.10	2.08	-0.96	-1.18	-2.16
Asia	-0.86	-6.46	3.04	-2.17	-3.60	-2.76

*Notes:* Each column of this table presents the t-statistics (top) and coefficient estimates (bottom, in parentheses) for a pooled regression of the form  $L(\hat{\theta}_t^i, M_{0,t}^i) - L(\hat{\theta}_t^i, M_{j,t}^i) = \beta_j' \mathbf{X}_{t-1}^i + \gamma_j' \mathbf{Z}^i + \varepsilon_{j,t}^i$ , for  $t = 1, 2, \dots, T$ ;  $i = 1, 2, \dots, 31$ , where  $M_{0,t}^i$  is RV5min,  $M_{j,t}^i$  is a competing realized measure listed in the table header,  $\mathbf{X}_{t-1}^i$  are the set of 5 explanatory variables listed in the first 5 rows of first column, and  $\mathbf{Z}^i$  are the set of 8 categorical variables listed in the last 8 rows of the first column. All 31 assets are included in each panel regression, and T=2860 (though panel is unbalanced). All estimators are calendar-time sampled, transaction price estimators. Statistically significant results (at 5% level) are shaded.

## References

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