Matlab Code and Corrected Tables for:

"Exploiting the Errors: A Simple Approach for Improved Volatility Forecasting"

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Abstract

The tables below are generated using the data and Matlab code available under the research sections of the authors' web pages. The tables in the original paper were generated using the Ox programming language, and in preparing this Matlab toolbox we corrected some bugs in the original code. The main conclusions of the paper all remain unchanged, but some of the numbers in the tables below differ slightly from those in the published tables. All of the corrected tables can be reproduced by running the two Matlab files: the code in `BPQ2016_Replication_SP500.m` generates the results for the S&P 500 market index, and the code in `BPQ2016_Replication_Stocks.m` generates the results for the individual stocks.

Table 2: Summary Statistics

Company	Min	Mean	Median	Max	AR	ARQ
SP500	0.043	1.175	0.629	60.563	0.651	0.983
AXP	0.088	4.603	2.184	290.338	0.602	0.949
BA	0.167	3.371	2.147	79.760	0.630	0.822
CAT	0.207	3.810	2.401	127.119	0.727	0.896
CSCO	0.234	5.120	2.742	96.212	0.715	0.942
CVX	0.105	2.286	1.483	139.984	0.652	1.046
DD	0.093	3.327	2.165	81.721	0.706	0.956
DIS	0.135	3.641	2.030	129.661	0.629	0.772
GE	0.131	3.440	1.794	173.223	0.681	0.987
HD	0.171	3.798	2.161	133.855	0.633	0.992
IBM	0.115	2.464	1.340	72.789	0.654	0.890
INTC	0.208	4.654	2.674	89.735	0.731	0.968
JNJ	0.062	1.680	0.999	58.338	0.614	0.933
JPM	0.114	5.420	2.552	261.459	0.716	1.060
KO	0.049	2.011	1.154	54.883	0.618	0.834
MCD	0.090	2.678	1.680	130.103	0.390	0.672
MMM	0.140	2.278	1.358	123.197	0.495	0.748
MRK	0.127	2.758	1.718	223.723	0.372	0.708
MSFT	0.166	3.087	1.824	59.164	0.718	0.889
NKE	0.192	3.431	1.980	84.338	0.579	0.785
PFE	0.176	2.822	1.809	60.302	0.570	0.837
PG	0.085	2.007	1.064	80.124	0.587	0.786
TRV	0.098	3.579	1.637	273.579	0.647	0.915
UNH	0.222	4.145	2.304	169.815	0.614	0.846
UTX	0.126	2.793	1.658	92.105	0.648	0.883
VZ	0.145	2.788	1.637	99.821	0.646	0.859
WMT	0.148	2.761	1.443	114.639	0.611	0.810
XOM	0.114	2.348	1.476	130.667	0.668	0.997

Table 3: In-Sample Estimation Results

	AR	HAR	ARQ	HARQ	HARQ-F
β_0	0.4109	0.1123	0.0892	-0.0098	-0.0187
	(0.1045)	(0.0615)	(0.0666)	(0.0617)	(0.0573)
β_1	0.6508	0.2273	0.9828	0.5929	0.5725
	(0.1018)	(0.1104)	(0.0768)	(0.0839)	(0.0775)
β_2		0.4903		0.3586	0.4368
		(0.1352)		(0.1284)	(0.1755)
β_3		0.1864		0.0976	0.0509
		(0.1100)		(0.1052)	(0.1447)
β_{1Q}			-0.5139	-0.3602	-0.339
			(0.0708)	(0.0637)	(0.0730)
β_{2Q}					-0.1406
					(0.3301)
β_{3Q}					0.0856
					(0.3416)
R^2	0.4235	0.5224	0.5263	0.5624	0.5628
MSE	3.1049	2.5722	2.5512	2.357	2.3546
QLIKE	0.2111	0.1438	0.1529	0.1356	0.1378
$\bar{R}^2$ Stocks	0.3975	0.4852	0.4676	0.5090	0.5139
$\overline{MSE}$ Stocks	17.4559	14.9845	15.2782	14.1702	14.0154
$\overline{QLIKE}$ Stocks	0.2095	0.1496	0.1804	0.147	0.1546

Table 4: Out-of-Sample Forecast Losses

			AR	HAR	HAR-J	CHAR	SHAR	ARQ	HARQ	HARQ-F
S&P500										
MSE	RW		0.9166	1.0000	0.9176	0.9583	0.8375	**0.8115**	0.8266	0.7950
	IW		1.2315	1.0000	0.9676	0.9707	0.9012	0.9587	**0.8944**	0.9312
QLIKE	RW		1.5281	1.0000	1.0117	1.0201	**0.9399**	1.1294	1.0168	1.2934
	IW		1.7216	1.0000	0.9716	0.9829	0.8718	1.1845	0.8809	**0.8686**
Individual Stocks										
MSE	RW	Avg	1.1505	1.0000	1.0151	1.0080	1.0083	0.9659	**0.9349**	1.0149
	IW	Med	1.1730	1.0000	1.0115	1.0158	1.0020	0.9864	**0.9418**	1.0263
	RW	Avg	1.2130	1.0000	1.0040	1.0013	0.9947	1.0371	**0.9525**	1.0071
	IW	Med	1.2161	1.0000	1.0028	1.0010	0.9968	1.0396	**0.9525**	0.9660
QLIKE	RW	Avg	1.4204	1.0000	1.0018	0.9999	0.9902	1.1498	**0.9902**	1.1516
	IW	Med	1.4044	1.0000	0.9976	1.0025	0.9941	1.1781	**0.9916**	1.1051
	RW	Avg	1.5803	1.0000	0.9930	1.0148	0.9829	1.2024	**0.9487**	0.9843
	IW	Med	1.5565	1.0000	0.9959	1.0163	0.9887	1.1732	**0.9550**	0.9630

Table 5: Stratified Out-of-Sample Forecast Losses

			AR	HAR	HAR-J	CHAR	SHAR	ARQ	HARQ	HARQ-F
Bottom 95% RQ_t										
S&P500										
MSE	RW		1.0836	1.0000	0.9856	0.9789	0.9400	0.9557	**0.9300**	0.9755
	IW		1.1365	1.0000	0.9778	0.9887	0.9353	0.9851	**0.9254**	0.9317
QLIKE	RW		1.5250	1.0000	1.0047	1.0232	**0.9396**	1.1127	1.0133	1.1940
	IW		1.7434	1.0000	0.9733	0.9865	0.8733	1.1950	0.8778	**0.8626**
Individual Stocks										
MSE	RW	Avg	1.1715	1.0000	0.9935	1.0018	0.9860	1.0184	**0.9570**	1.0068
	IW	Med	1.1617	1.0000	0.9932	0.9994	0.9854	1.0183	**0.9626**	0.9854
	RW	Avg	1.2353	1.0000	0.9924	1.0010	0.9876	1.0734	**0.9672**	0.9768
	IW	Med	1.2203	1.0000	0.9941	1.0030	0.9885	1.0650	0.9715	**0.9626**
QLIKE	RW	Avg	1.4274	1.0000	0.9975	1.0050	0.9885	1.1293	**0.9804**	1.1181
	IW	Med	1.3838	1.0000	0.9957	1.0096	0.9931	1.1268	**0.9814**	1.0628
	RW	Avg	1.6004	1.0000	0.9962	1.0226	0.9793	1.1905	**0.9385**	0.9656
	IW	Med	1.5783	1.0000	0.9979	1.0202	0.9835	1.1611	**0.9440**	0.9562
Top 5% RQ_t										
S&P500										
MSE	RW		0.8804	1.0000	0.9028	0.9538	0.8153	0.7802	0.8042	**0.7559**
	IW		1.2561	1.0000	0.9650	0.9660	0.8923	0.9518	**0.8863**	0.9311
QLIKE	RW		1.5671	1.0000	1.1020	0.9794	**0.9430**	1.3452	1.0622	2.5837
	IW		1.4147	1.0000	0.9477	0.9334	**0.8507**	1.0365	0.9252	0.9525
Individual Stocks										
MSE	RW	Avg	1.1515	1.0000	1.0249	1.0160	1.0208	0.9351	**0.9201**	1.0297
	IW	Med	1.1478	1.0000	1.0223	1.0266	1.0097	0.9388	**0.9142**	1.0493
	RW	Avg	1.2069	1.0000	1.0073	0.9980	0.9990	1.0179	**0.9420**	1.0136
	IW	Med	1.2019	1.0000	1.0088	1.0033	0.9999	1.0331	**0.9417**	0.9665
QLIKE	RW	Avg	1.3777	1.0000	1.0542	**0.9583**	1.0209	1.4853	1.1820	1.6123
	IW	Med	1.3461	1.0000	0.9980	**0.9145**	1.0227	1.4038	1.1725	1.5470
	RW	Avg	1.3228	1.0000	0.9501	**0.9135**	1.0263	1.3720	1.0908	1.2428
	IW	Med	1.3528	1.0000	0.9551	**0.9263**	1.0153	1.2928	1.0197	1.0226

Table 6: In-Sample Weekly and Monthly Model Estimates

	$h = 5$				$h = 22$			
	HAR	HARQ	HARQ-F	HARQ-h	HAR	HARQ	HARQ-F	HARQ-h
β_0	0.1717	0.0977	0.0576	0.0170	0.3417	0.2914	0.2845	0.2930
	(0.0673)	(0.0687)	(0.0804)	(0.0786)	(0.0672)	(0.0719)	(0.1113)	(0.1157)
β_1	0.1864	0.4078	0.3408	0.1898	0.1049	0.2548	0.2124	0.1043
	(0.0534)	(0.0912)	(0.0847)	(0.0507)	(0.0225)	(0.0692)	(0.0404)	(0.0225)
β_2	0.3957	0.3159	0.5623	0.6826	0.3342	0.2802	0.4538	0.3364
	(0.1108)	(0.1041)	(0.1595)	(0.1811)	(0.1129)	(0.0966)	(0.1981)	(0.1181)
β_3	0.2709	0.2172	0.0862	0.1609	0.2695	0.2332	0.1122	0.3225
	(0.1066)	(0.1122)	(0.1381)	(0.1321)	(0.0934)	(0.1014)	(0.1402)	(0.1007)
β_{1Q}		-0.2182	-0.1488			-0.1476	-0.1032	
		(0.0447)	(0.0409)			(0.0457)	(0.0193)	
β_{2Q}			-0.4404	-0.5648			-0.3158	
			(0.1469)	(0.1594)			(0.1699)	
β_{3Q}			0.2173				0.2458	-0.1847
			(0.3062)				(0.2440)	(0.3189)

Table 7: Weekly Out-of-Sample Forecast Losses

			AR	HAR	HAR-J	CHAR	SHAR	ARQ	HARQ	HARQ-F	HARQ-h
S&P500											
MSE	RW		1.1448	1.0000	1.0401	0.9920	0.9019	1.0798	0.9476	1.2142	**0.8881**
	IW		1.3509	1.0000	0.9460	0.9673	**0.8365**	1.0861	0.9031	0.9171	0.9232
QLIKE	RW		1.5565	1.0000	1.0282	1.0420	0.9353	1.1889	**0.9161**	1.2558	0.9475
	IW		1.8800	1.0000	0.9477	0.9870	0.8735	1.3716	0.8536	**0.7539**	0.7996
Individual Stocks											
MSE	RW	Avg	1.2902	1.0000	0.9872	0.9960	0.9864	1.0985	0.9838	1.0235	**0.9766**
	IW	Med	1.2815	1.0000	0.9901	0.9946	0.9944	1.1148	0.9790	1.0037	**0.9467**
	RW	Avg	1.4259	1.0000	0.9938	1.0003	0.9955	1.2126	0.9627	0.9601	**0.9477**
	IW	Med	1.4385	1.0000	0.9908	1.0008	0.9922	1.2094	0.9574	**0.9257**	0.9271
QLIKE	RW	Avg	1.6563	1.0000	0.9942	1.0124	0.9820	1.2111	**0.9309**	1.0668	0.9874
	IW	Med	1.6541	1.0000	0.9954	1.0165	0.9834	1.1989	**0.9431**	1.0686	0.9865
	RW	Avg	1.9062	1.0000	0.9966	1.0279	0.9770	1.4147	0.9066	**0.8529**	0.8530
	IW	Med	1.8583	1.0000	0.9988	1.0252	0.9792	1.3971	0.9211	**0.8401**	0.8615

Table 8: Monthly Out-of-Sample Forecast Losses

			AR	HAR	HAR-J	CHAR	SHAR	ARQ	HARQ	HARQ-F	HARQ-h
						S&P500					
MSE	RW		1.1399	1.0000	0.9660	0.9639	**0.9557**	1.0958	1.0707	1.3486	1.2190
	IW		1.2410	1.0000	1.0126	1.0107	1.0119	1.1456	0.9667	**0.9338**	0.9832
QLIKE	RW		1.2423	1.0000	0.9779	0.9909	**0.9527**	1.0505	0.9817	1.1188	1.0472
	IW		1.4157	1.0000	0.9998	0.9937	0.9843	1.2144	0.9368	**0.8447**	0.8842
						Individual Stocks					
MSE	RW	Avg	1.2243	1.0000	1.0074	1.0159	0.9924	1.0966	0.9953	1.0204	**0.9761**
	IW	Med	1.2609	1.0000	1.0055	1.0105	0.9950	1.1001	0.9975	0.9968	**0.9626**
	RW	Avg	1.4127	1.0000	0.9967	1.0123	0.9907	1.2366	0.9770	**0.9723**	0.9815
	IW	Med	1.4052	1.0000	0.9993	1.0145	0.9927	1.2182	0.9692	**0.9480**	0.9703
QLIKE	RW	Avg	1.4107	1.0000	0.9995	1.0144	0.9909	1.1325	0.9486	0.9139	**0.8823**
	IW	Med	1.4251	1.0000	1.0001	1.0123	0.9928	1.1213	0.9481	0.8786	**0.8642**
	RW	Avg	1.6612	1.0000	0.9966	1.0257	0.9885	1.3519	0.9371	**0.8185**	0.8278
	IW	Med	1.6294	1.0000	0.9997	1.0296	0.9912	1.3619	0.9442	**0.8244**	0.8442

Table 9: HAR Models based on Noise-Robust RVs versus HARQ Model

			RV	SS-RV	TS-RV	RK	PA-RV
					S&P500		
MSE	RW		1.2574	1.0800	1.3472	1.3443	1.3521
	IW		1.1290	1.1882	1.2468	1.1769	1.1604
QLIKE	RW		1.0025	1.0129	1.1476	1.0493	1.0331
	IW		1.1487	1.1424	1.2637	1.4182	1.3608
					Individual Stocks		
MSE	RW	Avg	1.0763	1.0795	1.1793	1.0881	1.0519
	IW	Med	1.0618	1.0756	1.1698	1.0890	1.0594
	RW	Avg	1.0523	1.0787	1.1350	1.0658	1.0571
	IW	Med	1.0499	1.0659	1.1212	1.0787	1.0585
QLIKE	RW	Avg	1.0131	1.0178	1.0963	1.0511	1.0403
	IW	Med	1.0085	1.0160	1.0994	1.0449	1.0452
	RW	Avg	1.0555	1.0443	1.1299	1.1576	1.1210
	IW	Med	1.0471	1.0376	1.1167	1.1370	1.1328

Table 10: HARQ versus HAR Models based on Noise-Robust RVs

			RV	SS-RV	TS-RV	RK	PA-RV
					S&P500		
MSE	RW		0.7953	0.9308	0.9343	0.7829	0.8689
	IW		0.8857	0.8363	0.9499	0.8674	0.8625
QLIKE	RW		0.9975	1.0582	0.9433	0.9886	1.1241
	IW		0.8705	0.8903	0.9174	0.8590	0.8613
					Individual Stocks		
MSE	RW	Avg	0.9349	0.9359	0.9548	0.9738	0.9929
	IW	Med	0.9418	0.9336	0.9521	0.9621	0.9766
	RW	Avg	0.9525	0.9450	0.9614	0.9846	0.9708
	IW	Med	0.9525	0.9521	0.9672	0.9687	0.9718
QLIKE	RW	Avg	0.9902	0.9641	0.9746	1.0010	0.9880
	IW	Med	0.9916	0.9641	0.9807	0.9954	0.9853
	RW	Avg	0.9487	0.9420	0.9626	0.9510	0.9511
	IW	Med	0.9550	0.9422	0.9621	0.9456	0.9455

Table 11: Alternative IQ estimators.

IQ-estimator			RQ	TPQ	MedRQ	TrRQ	RQ_{15min}	Bootstrap
					S&P500			
MSE	RW		1.0000	1.0497	1.0254	1.0208	1.0590	**0.9925**
	IW		1.0000	1.1635	1.0321	0.9942	**0.9798**	0.9981
QLIKE	RW		1.0000	1.0933	1.1227	0.9971	1.0231	**0.9933**
	IW		1.0000	**0.9814**	1.0522	1.1991	1.0388	0.9998
					Individual Stocks			
MSE	RW	Avg	1.0000	1.0403	1.0139	1.0531	1.0586	**0.9936**
	IW	Med	**1.0000**	1.0497	1.0201	1.0378	1.0238	1.0003
	RW	Avg	1.0000	1.0211	1.0191	1.0491	1.0229	**0.9994**
	IW	Med	1.0000	1.0220	1.0259	1.0558	1.0125	**0.9998**
QLIKE	RW	Avg	1.0000	1.0040	1.0089	1.0541	1.0254	**0.9995**
	IW	Med	1.0000	0.9980	**0.9968**	1.0376	1.0015	0.9992
	RW	Avg	**1.0000**	1.0050	1.0047	1.0390	1.0014	1.0001
	IW	Med	**1.0000**	1.0040	1.0065	1.0303	0.9989	1.0001

Table 12: Alternative HARQ Specifications

			Alternative RQ Transformations					Adding $RQ^{1/2}$	
			RQ	$RQ^{1/2}$	$RQ^{-1/2}$	RQ^{-1}	$Log(RQ)$	HAR	HARQ
						S&P500			
MSE	RW		1.0037	**1.0000**	1.2123	1.2334	1.3313	1.1551	1.0018
	IW		1.0344	**1.0000**	1.1164	1.1374	1.0647	1.1166	1.1402
QLIKE	RW		**0.9484**	1.0000	1.0952	1.0950	1.8104	0.9916	**0.9916**
	IW		1.0222	**1.0000**	1.1319	1.3564	2.0143	1.0452	1.0089
						Individual Stocks			
MSE	RW	Avg	1.0108	**1.0000**	1.0808	1.0931	1.0329	1.0657	1.0251
	IW	Med	1.0112	**1.0000**	1.0577	1.0664	1.0336	1.0411	1.0167
	RW	Avg	1.0189	**1.0000**	1.0495	1.0644	1.0143	1.0334	1.0111
	IW	Med	1.0198	**1.0000**	1.0403	1.0598	1.0082	1.0215	1.0067
QLIKE	RW	Avg	**0.9973**	1.0000	1.0678	1.0814	1.3723	**0.9969**	1.0073
	IW	Med	**0.9847**	1.0000	1.0458	1.0579	1.3324	**0.9848**	1.0003
	RW	Avg	1.0263	**1.0000**	1.0961	1.1155	1.2903	1.0207	**0.9957**
	IW	Med	1.0241	**1.0000**	1.0778	1.0886	1.2084	1.0180	**0.9932**

Table 13: Alternative Q-Model In-Sample Estimates

	HAR-J	HARQ-J	CHAR	CHARQ	SHAR	SHARQ
β_0	0.1208	0.0045	0.1361	-0.0064	0.0692	-0.0766
	(0.0606)	(0.0561)	(0.0595)	(0.0618)	(0.0667)	(0.0613)
β_1	0.3599	0.6035	0.2657	0.5834		
	(0.0891)	(0.0882)	(0.0958)	(0.0967)		
β_2	0.4341	0.3519	0.4980	0.4189	0.4176	0.3527
	(0.1300)	(0.1285)	(0.1489)	(0.1524)	(0.1223)	(0.1260)
β_3	0.1856	0.1057	0.1751	0.1131	0.1530	0.0822
	(0.1068)	(0.1034)	(0.1201)	(0.1138)	(0.1013)	(0.0997)
β_J	-1.0033	-0.3393				
	(0.3668)	(0.2857)				
β_1^+					-0.3734	-0.2027
					(0.1772)	(0.2054)
β_1^-					1.1282	1.5723
					(0.2773)	(0.2658)
β_{1Q}		-0.3266		-0.5410		
		(0.0617)		(0.1800)		
β_{1Q}^+						-1.3227
						(0.3632)
β_{1Q}^-						0.2485
						(0.1316)
R^2	0.5376	0.5638	0.5347	0.5526	0.5751	0.5972
MSE	2.4908	2.3495	2.5064	2.4097	2.2887	2.1693
QLIKE	0.1538	0.1336	0.1442	0.1377	0.3315	0.2154
$\overline{R}^2$ Stocks	0.4913	0.5207	0.4891	0.5107	0.4987	0.5242
$\overline{MSE}$ Stocks	14.8201	13.4522	14.9265	14.1870	14.5414	13.6868
$\overline{QLIKE}$ Stocks	0.1492	0.1492	0.1509	0.1454	0.1496	0.1534

Table 14: Alternative Q-Model Out-of-Sample Forecast Losses

			HARQ	HARQ-J	CHARQ	SHARQ
S&P500						
MSE	RW		0.8266	0.9243	0.8951	4.4822
	IW		0.8944	0.9335	1.0609	0.9384
QLIKE	RW		1.0168	0.9653	1.0235	2.2180
	IW		0.8809	0.9015	0.8825	1.2529
Individual Stocks						
MSE	RW	Avg	0.9349	0.9397	0.9525	0.9643
		Med	0.9418	0.9513	0.9539	0.9697
	IW	Avg	0.9525	0.9666	0.9451	0.9640
		Med	0.9525	0.9662	0.9548	0.9563
QLIKE	RW	Avg	0.9902	0.9902	0.9879	1.0997
		Med	0.9916	0.9952	0.9900	1.0606
	IW	Avg	0.9487	0.9548	0.9306	0.9966
		Med	0.9550	0.9594	0.9277	1.0050