ON THE PREDICTABILITY OF TICK BY TICK EXCHANGE RATES USING THE STRUCTURE OF THE ORDER BOOK

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Outline

2 **Genetic Algorithm**

3 Testing procedures
  - Pesaran-Timmermann test
  - Anatolyev-Gerko test
  - White's Reality Check

4 Results

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Genetic Algorithm

- Genetic programming is a computer based optimization procedures which uses the evolutionary principles.

- The genetic algorithm evaluates the fitness of various candidate solutions using the given objective function of the optimization problem and provides as an output solutions that have higher fitness values.

- Operation of crossover and mutation are applied to create new generation based on the genetic information of more fit solution candidates.

Genetic tree consists of:

- Functions

- Variables

- Real Numbers

binary algebraic
$\{+, -, *, /, \max, \min\}$

binary order relations
$\{<, >, \leq, \geq, =\}$

logical operations
$\{\text{and}, \text{or}\}$

unary functions
$\{\text{abs}, -\}$

price	bestbid
ret	bestoff
lagpr	bestbidq
lagret	bestoffq
maxpr	quant
minpr	liqbid
avgpr	liqoff
avgret	depthbid
	depthoff
	time

Example
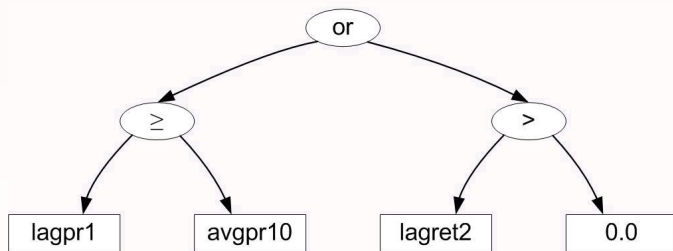
With this trading rule the investor is going to take a long position in
USD if $(\text{lagpr1} \geq \text{avgpr10}) \text{and} (\text{lagret2} > 1.0)$ and short one otherwise.

The evolutionary algorithm

1. Create randomly the initial population $P(0)$ and initialize the number of iterations $i = 0$.

2. Set $i := i + 1$.

3. Evaluate fitness of each tree in the population using the fitness function.

4. Generate new population using genetic operations (crossover and mutation)

5. Repeat 2) – 5) while $i < N$.

Crossover: select two parents
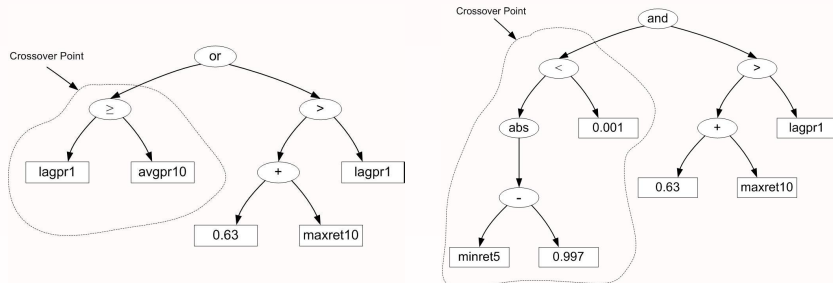
For both of parents we randomly select nodes to crossover

Crossover: get offsprings
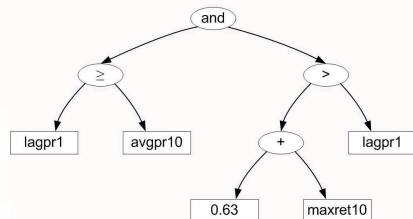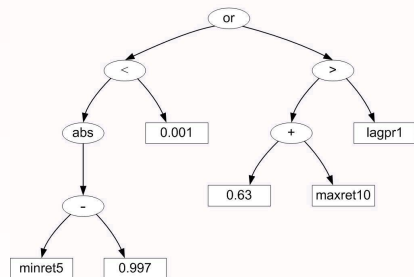
Two offsprings after the crossover operation

Mutation: randomly select a node ...
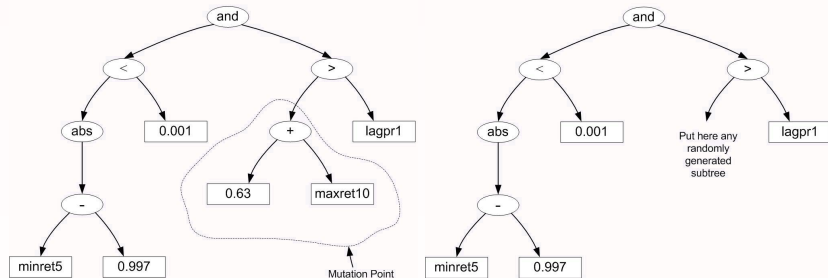
... and substitute it with a random subtree

Parameters

- population size – 100 individuals;

- number of evolutionary periods – $N = 50$;

- crossover rate – 40%;

- mutation probability – 0.0 for best 25% and 0.3 for others;

Fitness functions

- DC – percentage of correct predictions of directional changes;

- R – cumulative returns adjusted to the daily basis;

- R^{TC} – cumulative returns under transaction costs;

Data
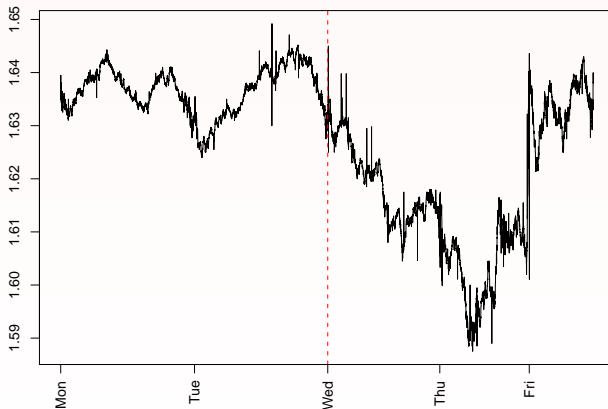
Tick-by-tick USD/DM exchange rate time series from 5.10.1998 to 9.10.1998

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Pesaran and Timmermann (1992)

- e_t – realised value of the exchange rate;

- z_t – its forecast;

$$P_{11} = P(z_t < 0, e_t < 0), \quad P_{12} = P(z_t < 0, e_t \geq 0),$$
$$P_{21} = P(z_t \geq 0, e_t < 0), \quad P_{22} = P(z_t \geq 0, e_t \geq 0)$$
$$P_{i0} = P_{i1} + P_{i2}, \quad\quad\quad P_{0i} = P_{1i} + P_{2i}.$$

$$H0 : \sum_{i=1}^{m} (\hat{P}_{ii} - \hat{P}_{i0}\hat{P}_{0i}) = 0$$

i.e., realised values and forecasts are independent

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P-T Statistic

$$s_n = \sqrt{n} V_n^{-\frac{1}{2}} S_n \overset{a}{\sim} N(0, 1),$$

where

$$S_n = \sum_{i=1}^{m} (\hat{P}_{ii} - \hat{P}_{i0} \hat{P}_{0i})$$

$$V_n = (\frac{\partial f(\mathbf{P})}{\partial \mathbf{P}})'_{\mathbf{P}=\hat{\mathbf{P}}} (\hat{\Psi} - \hat{\mathbf{P}}\hat{\mathbf{P}}') (\frac{\partial f(\mathbf{P})}{\partial \mathbf{P}})_{\mathbf{P}=\hat{\mathbf{P}}}$$

$$\hat{\Psi} = \mathrm{diag}(\hat{\mathbf{P}}),$$

$$(\frac{\partial f(\mathbf{P})}{\partial \mathbf{P}})_{\mathbf{P}=\hat{\mathbf{P}}} = \begin{cases} 1 - P_{0i} - P_{i0} & \text{for } i = j \\ -P_{j0} - P_{0i} & \text{for } i \neq j \end{cases}$$

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Anatolyev and Gerko (2005)

- r_t – observed log-returns of the exchange rate;

- $\hat{r}_t$ – forecasts, depend on past inform. $\mathcal{F}_{t-1} = \{r_{t-1}, r_{t-2}, ...\}$;

Strategy: take a long position in USD if $\hat{r}_t \geq 0$ and a short position if $\hat{r}_t < 0$;

One-period return from trading the strategy is $R_t = \text{sign}(\hat{r}_t) \cdot r_t$.

$$H_0 \colon E(r_t | \mathcal{F}_{t-1}) = \text{const}$$

i.e., $\hat{r}_t$ and r_t are independent.

A-G Statistic

$E(R_t)$ consistent estimators:

$$A_n = \frac{1}{n}\sum_t R_t$$

$$B_n = \left(\frac{1}{n}\sum_t \mathrm{sign}(\hat{r}_t)\right)\left(\frac{1}{n}\sum_t r_t\right).$$

$EP = \frac{A_n - B_n}{\sqrt{\hat{V}}} \xrightarrow{d} N(0,1)$

$\hat{V} = \frac{4}{n^2}\hat{p}_{\hat{r}}(1 - \hat{p}_{\hat{r}})\sum_t (r_t - \bar{r})^2$ with $\hat{p}_{\hat{r}} = \frac{1}{2}(1 + \frac{1}{n}\sum_t \mathrm{sign}(\hat{r}_t))$.

White (2000)

- Data snooping involves the re-use of the same sample data in multiple hypothesis testing

- not recognising the impact that prior decisions in the testing sequence have on the significance levels to be used at any stage subsequently down the chain.

- the Reality Check enables us to calculate true empirical *p*-values of the test statistic based on the null of no predictability beyond the benchmark.

The Reality Check Procedure

φ_k, $(k = 1, ..., M)$ – performance measure of the k-th trading rule relative to some benchmark;

The aim is to test whether there is a rule within the population that delivers superior performance to the benchmark.

$$H_0 : \max_{k=1,...,M} \varphi_k \leq 0$$

Test statistic: $\qquad\qquad V = \max_{k=1,...,M} \varphi_k.$

The Reality Check Procedure: *p*-values

$\varphi^*_{k,j}$ – performance measure of the *k*-th trading rule calculated using *j*-th bootstrap sample.

The empirical distribution based on the bootstrap realizations

$$V^*_j = \max_{k=1,...,M} (\varphi^*_{k,j} - \varphi_k), \, j = 1, ..., B.$$

White(2000) – distributions of *V* and V^* are asympt. equivalent.

Comparing *V* with the quantiles of the empirical distribution of V^* we obtain the Reality Check *p*-values which are suitable for testing the null hypothesis.

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Conclusions

- We examine the predictability of exchange rates on a transaction level basis using both past transaction prices and the structure of the order book;

- The Pesaran-Timmermann test shows clear ability to predict directional changes in the exchange rate;

- The economic value under transaction costs is shown to be significant out-of-sample using the Anatolyev-Gerkov test;

- Predictability and profitability depend critically on the frequency of trades which is controlled the inertia parameter k;

- These conclusions are confirmed using White's Reality Check;

- We do not find strong evidence that exploiting the order book structure aids predictability.

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$k = 0$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (ret ≤ minret10) or (lagpr1 > avgpr5)	55.35	52.90	5.786	-9.154	4.21	< 0.0001	2.47	0.0068	0.0175
2. (ret < maxret10) and (lagpr1 > min{avgpr10, avgpr20})	55.20	53.61	7.231	-2.317	5.23	< 0.0001	3.06	0.0011	0.0065
3. (ret < maxret10) or (lagpr1 > avgpr5)	55.08	53.67	8.208	-6.090	5.35	< 0.0001	3.49	0.0002	0.0055
4. (ret ≤ minret10) or (lagpr1 > avgpr10)	55.06	53.52	4.677	-6.345	5.12	< 0.0001	2.01	0.0222	0.0075
5. ((price ≥ maxpr20) or (maxret5 = lagret1) or (avgret20 ≤ maxret5)) and (price ≥ avgpr20)	55.00	53.88	-7.663	-12.569	5.62	< 0.0001	-3.49	>0.5000	0.0055
6. (lagpr1 ≥ avgpr10) or (lagpr1 > avgpr5)	54.98	53.63	2.284	-8.082	5.30	< 0.0001	1.00	0.1587	0.0055
7. (lagpr1 ≥ avgpr20) and (maxret5 = avgpr5) or (price ≥ avgpr20)	54.98	53.88	-8.089	-12.856	5.62	< 0.0001	-3.70	>0.5000	0.0055
8. lagpr1 > min{avgpr10, lagpr2}	54.96	54.00	2.760	-8.768	5.83	< 0.0001	1.20	0.1151	0.0055
9. (price ≥ avgpr20) and (maxret5 = lagret1) or (price > avgpr20)	54.94	53.84	-8.126	-12.938	5.56	< 0.0001	-3.71	>0.5000	0.0055
10. lagpr1 > min{avgpr5, avgpr10}	54.93	53.58	2.272	-8.154	5.21	< 0.0001	0.99	0.1611	0.0065
11. price > avgpr20	54.93	53.84	-8.126	-12.938	5.56	< 0.0001	-3.71	>0.5000	0.0055
12. (price ≥ avgpr20) or (maxret5 = avgpr5)	54.91	53.73	-8.217	-13.278	5.39	< 0.0001	-3.76	>0.5000	0.0055
13. minpr20 < minpr10 · lagret1	53.90	52.77	-2.096	-12.556	4.01	< 0.0001	-0.93	>0.5000	0.0024
14. lagpr1 > min{avgpr5, avgpr20}	54.89	53.46	2.657	-6.359	5.13	< 0.0001	1.17	0.1210	0.0075
15. price ≥ avgpr20	54.89	53.83	-8.153	-12.963	5.53	< 0.0001	-3.73	>0.5000	0.0055
16. lagpr1 > avgpr20	54.71	53.48	2.910	-2.701	5.03	< 0.0001	1.26	0.1038	0.0075
17. (lagpr1 > avgpr5) or (lagpr1 = avgpr10)	54.69	53.40	3.742	-2.701	4.93	< 0.0001	1.61	0.0537	0.0085
18. (price > avgpr10) or (ret = minret20)	54.69	54.98	3.742	-9.049	7.28	< 0.0001	-0.17	>0.5000	0.0025
19. lagpr1 > avgpr5	54.64	53.34	3.730	-9.108	4.84	< 0.0001	1.61	0.0537	0.0105
20. (price > avgpr10) or (minpr10 > minpr20)	54.60	52.42	-9.701	-13.766	3.53	0.0002	-4.51	>0.5000	0.0305
21. Average	**55.10**	**54.11**	**2.150**	**-6.123**	**5.98**	**<0.0001**	**0.93**	**0.1762**	**0.0055**

Trading rules based on the pure price information only. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

$k = 0.0005$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. avgret10 > minret20 · maxret20	56.01	51.28	6.040	3.133	1.07	0.1423	2.57	0.051	0.2345
2. avgret5 > minret20 · maxret20	55.57	50.67	7.315	4.193	0.61	0.2709	3.10	0.0010	0.3675
3. (minret10 ≥ ret) or (avgpr20 · lagret2 · maxret10 ≤ lagpr1)	56.60	50.87	4.629	-0.473	0.55	0.2912	2.02	0.0217	0.3115
4. (minret10 ≥ lagret2) or (avgpr20 · ret · avgret20 ≤ lagpr1)	55.72	54.04	6.728	1.692	3.25	0.0006	2.87	0.0021	0.0065
5. minret10 ≥ min{lagret2, ret}	56.16	51.95	6.261	1.308	1.35	0.0885	2.75	0.0030	0.1255
6. (lagret1 ≥ (price − avgpr20) · 1743.99) or (maxret10 = avgret20)	54.99	51.35	9.878	6.894	1.36	0.0869	4.46	<0.0001	0.2215
7. (price < avgpr10) or (price · minret20 < minpr5 · lagret1)	55.13	50.34	6.081	2.536	0.72	0.2358	2.99	0.0014	0.4355
8. (avgret10 < avgret5) or (avgpr5 > avgpr10 · maxret20 · minret5)	54.69	50.34	0.990	-3.196	0.71	0.2389	0.44	0.3300	0.4355
9. (minret10 ≥ ret) or (lagret1 ≥ lagret2)	54.99	52.29	3.267	-1.362	2.21	0.0136	1.52	0.0643	0.0955
10. (avgpr10 ≥ price) or (maxret10 > max{avgret10, ret})	54.40	49.80	6.137	2.966	0.43	0.3336	3.38	0.0004	0.5565
11. (minret20 > avgret20 · minret10) or (lagret1 ≥ lagret2)	54.55	50.27	-2.792	-6.504	0.63	0.2643	-1.44	>0.5000	0.4455
12. (minret10 = minret5) or (lagret1) or (maxret5 · minret10 > ret)	55.57	53.90	5.381	0.168	2.95	0.0016	2.32	0.0102	0.0085
13. avgpr5 > avgpr10 · maxret20 · minret5	54.40	52.15	5.909	2.349	1.47	0.0708	2.83	0.0023	0.1055
14. (minret10 ≥ ret) and ((lagpr2 − maxpr10| ≥ maxret5 − lagret2)	54.99	51.55	4.727	0.977	0.92	0.1788	2.41	0.0080	0.1785
15. (minret10 = minret5) or (lagpr1 > lagpr2)	54.40	50.61	1.714	-1.561	1.10	0.1357	0.87	0.1922	0.3805
16. (avgpr10 ≥ price) or (lagret1 > avgret20)	54.25	50.67	4.189	0.995	1.17	0.1210	2.17	0.0150	0.3675
17. (lagpr2 = minpr5) or (ret = minret10)	54.25	51.68	6.172	1.575	1.07	0.1423	2.96	0.0015	0.1575
18. (maxret10 > avgret10 · ret) and (minret10 = minret5)	54.25	51.14	3.813	-0.623	1.06	0.1446	1.67	0.0475	0.2595
19. (lagret1 > ret · 0.9994) and ((lagpr1 > maxpr10 · 0.9994) or (minret5 < 0.9994))	53.81	53.70	10.212	5.792	0.13	0.4483	-0.51	>0.5000	0.0105
20. (avgret10 < avgret5) or (avgret10 > lagret2 · maxret20)	53.67	50.53	-1.159	-5.829	3.54	0.0002	4.96	<0.0001	0.4675
21. Average	58.50	51.95	6.559	3.062	1.28	0.1002	2.49	0.0064	0.1255

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$k = 0.001$

	Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	(avgpr10 ≥ maxpr10 · ret) or (lagpr1 = avgpr10)	60.07	55.49	9.390	7.317	3.17	0.0008	4.52	<0.0001	0.0065
2.	avgpr10 ≥ maxpr10 · minret20	59.72	53.98	5.951	4.165	2.26	0.0119	2.57	0.0051	0.0325
3.	(price ≤ minpr20) and (ret = minret10)	59.36	53.43	6.524	5.092	2.05	0.0201	3.71	0.0001	0.0545
4.	(lagpr1 · lagret2 < avgpr10 · avgret5) or (price < avgpr10)	59.36	50.69	2.015	0.255	0.25	0.4013	0.91	0.1814	0.3005
5.	(avgret20 ≥ avgret10) or (price = minpr10)	59.36	52.34	5.302	3.292	1.44	0.0749	2.36	0.0091	0.1155
6.	(price < avgpr10) or (avgret20 ≥ avgret10)	59.01	52.47	5.979	4.05	1.61	0.0537	2.77	0.0028	0.1025
7.	(lagpr1 ≤ avgpr10) and (price ≤ avgpr10)	59.01	50.82	1.619	-0.120	0.33	0.3707	0.73	0.2327	0.2775
8.	(lagpr1 ≥ price) and (maxpr20 · minret20 ≥ price)	59.01	52.88	6.385	4.049	1.51	0.0655	2.73	0.0032	0.0785
9.	(price · maxret20 ≤ maxpr20) and (price ≤ avgpr10)	58.66	52.88	7.707	5.553	1.50	0.0668	3.30	0.0005	0.0785
10.	(price = minpr20) or (lagpr1 = minpr20)	58.31	52.47	5.969	4.141	1.27	0.1020	2.59	0.0048	0.1025
11.	(lagpr1 ≤ avgpr20) or (avgret20 > avgret10)	58.30	48.63	0.531	-1.295	-0.64	>0.5000	0.24	0.4052	0.6275
12.	avgpr10 ≥ price	57.95	54.12	8.870	6.395	2.21	0.0136	3.73	0.0001	0.0295
13.	(minpr10 > avgpr10 · avgret20) or (price < avgpr10)	57.95	53.98	8.826	6.366	2.14	0.0162	3.71	0.0001	0.0325
14.	price ≤ minpr20	57.95	53.98	8.987	7.007	2.12	0.0170	3.93	<0.0001	0.0325
15.	(maxpr5 · avgret5 < avgpr10) or (minret20 = ret)	56.89	54.95	7.784	5.312	2.65	0.0040	3.36	0.0004	0.0115
16.	(price ≤ avgpr10) or (price ≤ minpr5)	57.60	53.98	8.636	6.138	2.14	0.0162	3.63	0.0001	0.0325
17.	(lagpr2 · lagret2 ≥ minpr20) and (lagpr1 · avgret5 ≥ price)	57.60	53.16	7.288	4.500	1.69	0.0455	3.09	0.0010	0.0655
18.	price = minpr10	57.24	54.12	8.214	5.980	2.19	0.0143	3.52	0.0002	0.0295
19.	(minpr5 ≥ price) or (avgpr5 ≥ lagpr1)	56.54	53.02	3.749	1.613	1.73	0.0418	1.63	0.0516	0.0735
20.	(lagpr1 < avgpr5) or (avgret20 > avgret5)	55.83	49.73	0.726	-1.453	-0.09	>0.5000	0.32	0.3745	0.4465
21.	Average	58.66	54.12	8.051	5.763	2.19	0.0143	3.42	0.0003	0.0295

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$k = 0.005$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (minret20 = ret) or (lagret1 ≤ minret20)	84.00	60.38	4.085	3.711	2.21	0.0136	1.76	0.0392	0.0865
2. (minret5 · maxret10 ≤ avgret5) or (minpr20 = lagpr1)	76.00	60.38	4.974	4.604	2.21	0.0136	2.21	0.0136	0.0865
3. minret5 ≥ ret	76.00	72.64	9.634	9.145	5.44	<0.0001	4.19	<0.0001	0.0015
4. maxpr5 ≥ max{price, lagpr2}	72.00	66.04	6.027	5.582	3.53	0.0002	2.63	0.0043	0.0185
5. (lagpr2 ≥ maxpr20 · minret10) or (ret = minret5)	72.00	66.04	7.637	7.207	3.53	0.0002	3.35	0.0004	0.00185
6. (lagpr1 = minpr10) or (lagpr1 = maxpr5)	72.00	42.45	-3.324	-3.627	-1.75	>0.5000	-1.53	>0.5000	0.8345
7. (ret ≤ minret10) or (avgpr20 ≥ max{avgpr10, lagpr1}	72.00	64.15	6.356	5.981	3.13	0.0009	2.89	0.0019	0.0295
8. (max{price, avgpr20} < lagpr1) or (maxret5 = lagret1)	72.00	69.81	8.085	7.639	4.70	<0.0001	3.59	0.0002	0.0045
9. lagpr1 ≥ maxpr5	68.00	55.66	2.026	1.843	1.75	0.0401	1.13	0.1292	0.2225
10. price < maxpr5	68.00	67.92	8.212	7.751	4.01	<0.0001	3.54	0.0002	0.0125
11. (price < lagpr2) and (lagpr2 < avgpr5)	68.00	64.15	4.847	4.491	3.45	0.0003	2.45	0.0071	0.0295
12. (price < avgpr10) or (minpr10 = lagpr1)	68.00	61.32	5.565	5.220	2.47	0.0068	2.59	0.0048	0.0725
13. (ret < maxret20) and (ret · maxret10 < lagret2)	68.00	67.92	9.070	8.649	4.24	<0.0001	4.03	<0.0001	0.0125
14. maxpr5 · minret10 ≤ lagpr2	64.00	62.26	6.385	6.031	2.62	0.0044	2.83	0.0023	0.0595
15. (ret · maxret10 < lagret2) and (lagret2 < maxret10)	64.00	66.04	6.872	6.537	4.08	<0.0001	3.32	0.0005	0.0185
16. (ret < lagret1) and (lagret2 < maxret5)	64.00	66.98	5.460	5.074	3.90	<0.0001	2.57	0.0051	0.0135
17. (ret < lagret1) and (lagpr2 < maxpr5)	64.00	72.64	7.541	7.062	5.33	<0.0001	3.30	0.0005	0.0015
18. (ret < lagret1) or (lagret1 ≤ minret20)	64.00	66.98	5.956	5.561	3.85	0.0001	2.75	0.0030	0.0135
19. (ret ≤ lagret1) or (lagpr1 ≤ min{minpr10, avgpr1})	64.00	61.32	4.091	3.752	2.50	0.0062	1.81	0.0351	0.0725
20. price ≤ lagpr2	64.00	66.04	7.573	7.143	3.49	0.0002	3.21	0.0007	0.0185
21. Average	**76.00**	**67.92**	**8.340**	**7.885**	**3.97**	**<0.0001**	**3.54**	**0.0002**	**0.0125**

Trading rules based on the pure price information only. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0.01$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (1.6369 > avgpr10 · ret) and (lagret2 >= avgret5)	100.00	56.41	1.536	1.414	0.79	0.2148	0.67	0.2514	0.2575
2. (1.6369 > avgpr5 · ret) and (lagret2 >= avgret5)	100.00	56.41	1.536	1.414	0.79	0.2148	0.67	0.2514	0.2575
3. (price ≤ maxpr10 · avgret10) and (maxret10 > lagret1)	100.00	38.46	-1.775	-1.886	-1.60	>0.5000	-0.98	>0.5000	0.7505
4. lagret2 > avgret5	83.33	46.15	-2.262	-2.39	-0.48	>0.5000	-1.01	>0.5000	0.5565
5. maxret5 < maxret10	83.33	56.41	1.498	1.383	0.88	0.1894	0.65	0.2578	0.2575
6. (avgpr5 > lagpr2) and (lagret1 < maxret20)	83.33	61.54	0.585	0.458	1.53	0.0630	0.26	0.3974	0.1525
7. minret5 > (0.167 + maxpr5) · 0.556	83.33	61.54	2.064	2.003	1.47	0.0708	0.90	0.1841	0.1525
8. (ret ≤ lagret1) and (avgret5 < avgret10)	83.33	66.67	3.966	3.862	2.63	0.0043	1.84	0.0329	0.0845
9. avgpr5 > lagpr1	83.33	58.97	-0.451	-0.610	1.16	0.1230	-0.22	>0.5000	0.1985
10. maxret10 > lagret1	83.33	35.90	-2.186	-2.284	-2.27	>0.5000	-1.29	>0.5000	0.8065
11. lagret2 = maxret5	83.33	51.28	0.897	0.817	0.08	0.4681	0.49	0.3121	0.4055
12. avgpr10 < minpr5	83.33	43.59	-1.156	-1.228	-1.43	>0.5000	-0.66	>0.5000	0.6205
13. (lagpr2 > lagpr1) and (avgpr10 ≥ avgpr5)	66.67	53.85	-0.404	-0.517	0.47	0.3192	-0.22	>0.5000	0.3055
14. minret20 < minret10	66.67	53.85	0.372	0.299	0.49	0.3121	0.24	>0.5000	0.3055
15. lagret1 < 1	66.67	51.28	0.388	0.254	0.15	0.4404	0.17	0.4325	0.4055
16. price > maxpr10	66.67	51.28	-0.055	-0.062	0.00	0.5000	0.00	0.5000	0.4055
17. minret10 = avgret5	66.67	51.28	-0.055	-0.061	0.00	0.5000	0.00	0.5000	0.4055
18. avgpr10 ≥ lagpr1	66.67	66.67	0.786	0.619	2.20	0.0139	0.35	0.3632	0.0845
19. lagret2 = avgret10	66.67	51.28	-0.055	-0.062	0.00	0.5000	0.00	0.5000	0.4055
20. sell	66.67	51.28	-0.055	-0.061	0.00	0.5000	0.00	0.5000	0.4055
21. Average	83.33	64.10	2.310	2.208	2.27	0.0116	1.11	0.1335	0.1105

Trading rules based on the pure price information only. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (bestbid > avgpr20) or (bestbid > price)or(bestbid > bestbid2)	58.61	57.30	6.378	-5.628	10.70	< 0.0001	2.61	0.0045	<0.001
2. (maxpr20 < bestoff) or (bestbid > avgpr20) or (bestbid > price)	58.61	57.05	6.307	-3.00	10.32	< 0.0001	2.60	0.0047	<0.001
3. (bestbid > min{avgpr20, price}) or (offcount < 0.4376 + lagpr2)	58.07	56.80	6.056	-2.923	10.01	< 0.0001	2.51	0.0060	<0.001
4. (bestbid > avgpr20) or (bestbid > price)	57.93	56.76	6.247	-2.748	9.95	< 0.0001	2.59	0.0048	<0.001
5. (bestbid2 < bestbid) or (minpr5 < bestbid)	57.84	56.64	4.809	-7.517	9.71	< 0.0001	1.98	0.0239	<0.001
6. bestbid > min{depthbid1, offcount, minpr5, avgpr20}	57.60	56.45	4.770	-5.067	9.45	< 0.0001	1.98	0.0239	<0.001
7. (maxpr5 ≥ avgpr20) and (bestoff ≥ maxpr5)	57.35	56.84	4.571	-3.750	10.36	< 0.0001	1.96	0.0250	<0.001
8. (bestoff = maxpr5) or (bestoff > maxpr10)or(4.3234 ≥ bidcount1 · minret20)	57.29	56.93	8.130	-2.763	10.14	< 0.0001	3.31	0.0005	<0.001
9. (bestoff ≥ avgpr20) and (bestoff ≥ maxpr5)	57.10	56.91	4.976	-4.467	10.26	< 0.0001	2.09	0.0183	<0.001
10. (5 > depthbid) or (bestbid > bestbid2)or(maxpr10 ≤ max{lagret2 · max{bestbid2, bestoff}, bestbid})	57.06	55.55	3.871	-6.979	8.14	< 0.0001	1.61	0.0537	<0.001
11. (bestoff = maxpr5) or (bestoff > maxpr10)	56.97	57.07	8.135	-2.662	10.41	< 0.0001	3.33	0.0004	<0.001
12. (maxpr10 < bestoff) or (ret ≤ minret5)	56.95	56.26	9.653	-3.880	9.20	< 0.0001	3.93	<0.0001	<0.001
13. (maxpr10 = lagpr1) or (min{maxpr10, depthoff} ≤ bestoff)or(bidcount · depthbid ≤ min{time2.5 + bestbid4} · (9.3 − lagpr2))	56.87	57.07	9.737	-0.552	10.32	< 0.0001	3.93	<0.0001	<0.001
14. minpr5 < bestbid	56.75	56.07	6.324	-5.207	8.85	< 0.0001	2.59	0.0048	<0.001
15. (bestbid > minpr20) or (|bestoffq1 − bidcount2| ≤ 0.14 + max {iqoff2, $\frac{bidcount2}{4.38}$})	56.56	55.20	2.864	-4.045	8.33	< 0.0001	1.31	0.0951	<0.001
16. maxpr10 ≤ bestoff	56.29	56.85	6.261	-2.858	10.33	< 0.0001	2.66	0.0039	<0.001
17. (bestoff ≥ maxpr20) or (offcount2 < 1.5)	56.25	55.10	2.188	-4.491	8.46	< 0.0001	1.06	0.1446	<0.001
18. (bestoff ≥ maxpr20) and (liqoff · max{time1, time2} ≤ avgret5 · avgret10 · depthoff2)	56.21	55.16	4.367	-2.428	8.57	< 0.0001	2.08	0.0188	<0.001
19. (bestoff > avgpr5) and (bestoff > avgpr20)	56.17	55.27	0.676	-6.816	7.70	< 0.0001	0.28	0.3898	<0.001
20. bestoff ≥ maxpr20	56.15	55.16	4.367	-2.428	8.57	< 0.0001	2.08	0.0188	<0.001
21. Average	**58.78**	**57.30**	5.821	-3.202	10.72	<0.0001	2.40	0.0082	<0.001

Trading rules based on the all order book information. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives a buy signal if more than 9 of best 19 rules give a buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.0005$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (price < bestoff) and (min{3.61 + offcount2, |2 · bestoffiq1 − lagpr2 + depthbid2|} < depthoff)	60.24	52.86	1.103	-3.133	2.55	0.0054	0.47	0.3192	0.0055
2. (price < bestoff) and (depthoff > 14)	59.06	53.13	3.529	-0.722	2.72	0.0033	1.48	0.0694	0.0025
3. (maxref5-4.0661−|quant1−bestoffiq2| bestbidq < 2.1426) and ((bestoff1 ≥ maxpr20) or (bestbid > minpr5))	59.06	54.00	3.411	-0.604	3.00	0.0015	1.50	0.0668	0.0015
4. {(time1 ≤ bestoffiq2 + max{bestoffiq2, maxpr10}) or (bestoffiq2 ≥ bidcount2) or (lagre1 ≥ bestbidq1)) or (time1 ≥ ret)	58.76	48.22	-0.167	-4.744	-1.56	0.9418	-0.07	>0.5000	0.5915
5. (maxpr10 − lagre1 + bidcount1 ≤ bestoffiq2) or (1.8914 · quant ≤ bestoff1) or (minpr5 < bestbid) or (time2 − 4.5848 ≤ bestoffiq2)	58.47	52.72	1.635	-2.473	2.39	0.0084	0.70	0.2420	0.0055
6. (avgpr5 ≥ avgpr20 · min{minret10, $\frac{depthoff}{lagpr}$} · maxref20) or (depthoff ≥ max{bidcount2, maxret20} · lagpr1 · bestbid2)	58.47	49.83	4.098	1.731	0.43	0.0336	2.03	0.0212	0.2445
7. (depthoffiq2 ≥ 3) or (|quant1/(max{bestoffiq, quant} − 3.2)| > 2.99) or (3.1 ≤ bestoffiq1)	58.32	50.10	1.198	-3.210	0.20	0.4207	0.51	0.3050	0.1895
8. (price < bestoff1) or (price ≤ bestoff1)	58.03	50.44	6.019	2.332	0.87	0.1922	2.81	0.0025	0.1495
9. (maxpr10 ≤ bestoff1) or (price ≤ bestoff1)	57.44	50.50	6.422	2.776	0.94	0.1736	3.00	0.0013	0.1425
10. (minret10 = ret) or (bestbid > avgpr10)	57.14	51.98	2.921	-1.476	1.75	0.0401	1.24	0.1075	0.0245
11. (liqbid1 ≤ lagpr1 − lagpr2) or (9.2395 ≤ |max{min{liqbid, 8.10}, 7.3} − quant1 − depthoff2 + quant6.77|)	57.14	48.49	-4.297	-5.797	-0.79	>0.5000	-2.74	>0.5000	0.5235
12. (min{8.219, |bestoff − minpr5|, quant} ≥ liqoff) and (bestbidq2 < 8.6459)and(5.504 < offcount)	57.00	51.92	1.609	-1.295	2.03	0.0212	0.72	0.2358	0.0255
13. (min{depthoff2, 2.136} ≤ quant2) or (depthbid1 < depthoff2 − bestoff1)	57.00	48.69	-3.464	-5.546	-0.64	>0.5000	-1.62	>0.5000	0.4735
14. (bestoff2 + bidcount2 < offcount1) or (bidcount1 · liqbid ≥ 6.31 − bestoff2 · min{offcount1, bestoff1} · liqoff)	56.84	49.02	0.099	-1.719	-0.33	0.6293	0.03	0.4880	0.4025
15. (min{bestoff − minpr5, quant} ≥ liqoff) and (bestbidq2 < 8.6459)	56.85	51.92	2.065	-0.799	2.18	0.0146	0.93	0.1762	0.0255
16. {time1 ≥ ret) and (depthoff1 ≥ max{bestbidq + offcount, 9.87, offcount + max{bestbidq, minpr20 + ret + 0.17}}) and (bestbidq2 ≥ ret)	56.84	49.97	1.719	-2.718	0.10	0.4602	0.72	0.2358	0.2135
17. (min{max{bestoffiq2, 6.057}, quant2} ≥ 2.809) or (4.3 ≤ bestoffiq1 + bestoffiq2)	56.70	50.24	2.113	-2.269	0.21	0.4168	0.88	0.1894	0.1725
18. price < bestoff	56.55	53.40	5.924	1.426	3.00	0.0013	2.48	0.0066	0.0015
19. (min{bestoffiq1, 8.29} > 4.295 − $\frac{max\{bestbidq, bestbidq2\}}{bestoff2}$} or (offcount > max{max{bestbidq, bestbidq2} · bestbid1, |0.485 − depthbid1|})	56.41	50.58	-0.403	-4.455	0.52	0.3015	-0.17	>0.5000	0.1315
20. ((offcount > time2) and (bestoffiq1 > price)) or (max{depthbid2, bestoffiq2} < offcount1)	56.26	49.63	-0.944	-4.948	-0.23	>0.5000	-0.04	>0.5000	0.3705
21. Average	64.51	51.31	3.791	0.918	1.88	0.0301	1.91	0.0281	0.0655

Trading rules based on the all order book information. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives a buy signal if more than 9 of best 19 rules give a buy signal and sell otherwise.

$k = 0.001$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $((\max(\text{depthoff2} + \text{bestoffq} - \text{quant}, \text{offcount}) - \text{depthbid2} \geq 4.03)$ or $(\text{bestoffq} - \text{quant} \geq 4.03)or(\text{liqoff2} \geq \text{avgret10}))$ and $(\text{time2} < \text{depthbid2})$	63.25	45.82	-1.366	-2.964	-2.13	>0.5000	-0.63	>0.5000	0.7505
2. $(\text{bestoffq} = \text{offcount})$ or $(\text{quant2} \geq \text{bestoff})or((\text{bestbid1} = \text{minpr10})$ or $(\text{bestoffq} = \text{bidcount2}))$ and $(\frac{\text{offcount}}{1.84} > \text{bestoff1}))$	62.54	44.58	-1.097	-3.165	-2.83	>0.5000	-0.49	>0.5000	0.8735
3. $((\text{time} \leq \text{avgpr5})$ and $(\text{bidcount2} \geq \frac{5.52}{\text{time-bestoffq}})$ and $(\text{bestbidq2} \geq \text{avgret10}))$ or $(\text{offcount} < \text{minpr5})$ or $((\text{time} < \text{bidcount2})$ and $(\text{quant1} \geq \text{lagpr1}))$	61.13	46.36	-4.426	-6.269	-2.23	>0.5000	-1.96	>0.5000	0.6765
4. $(\text{quant1} \geq \text{avgpr10})$ or $((4.39 < \text{bestbidq}/1.115)$ and $(\text{time2} < \text{bestbidq2}))$	60.78	46.50	1.079	-1.206	-1.82	>0.5000	0.46	0.3228	0.6525
5. $(\text{quant} > 1)$ or $(\text{offcount1} \geq \text{depthbid})$	60.78	46.63	0.156	-1.958	-1.73	>0.5000	0.06	0.4671	0.6305
6. $(4 < \text{bestbidq})$ or$(\text{quant1} > 2.8)$ or $(\text{depthbid1} - \text{quant1} \leq \text{depthoff1})$ or $(4.54 \leq \text{bestbidq} - \text{avgret5})$	60.78	48.01	-0.016	-0.958	-0.93	>0.5000	-0.02	>0.5000	0.4175
7. $(\text{minpr5} = \text{bestbid1})$ or $(\text{quant} > \text{bestbid})$	60.42	47.33	0.254	-1.803	-1.26	>0.5000	0.11	0.4562	0.5335
8. $(\text{avgpr10} \geq \text{price})$ and $((\text{time2} < \text{depthbid})$ or $(6 \geq \text{bidcount1}))$	60.42	54.18	9.084	6.632	2.28	0.0113	3.70	0.0001	0.0025
9. $(\text{quant2} \geq \text{avgpr20})$ and $(\min(\text{avgpr20}, \text{price}) < \text{lagpr2})$	60.42	47.87	1.468	-1.133	-1.10	>0.5000	0.52	0.3015	0.4405
10. $(\text{avgpr10} > \max(\text{bestoff1}, \text{time}))$ or $(\text{avgpr10} < \text{quant2})$	60.42	46.91	0.276	-2.271	-1.53	>0.5000	0.11	0.4562	0.5965
11. $(\text{depthoff} > 7.26 + \text{depthbid1})$ or $(\text{bestoff} < \text{quant2})$	60.42	47.60	0.544	-0.715	-1.11	>0.5000	0.26	0.3974	0.4875
12. $(\text{avgpr10} > \text{time})$ or $(\text{avgpr10} < \max(\text{quant}, \text{quant2}))$	60.07	45.68	-0.528	-2.816	-2.20	>0.5000	-0.23	>0.5000	0.7655
13. $(\text{time} < \text{bestbid})$ or $(\text{bestoff} < \text{quant2})$	60.07	45.68	-0.528	-2.816	-2.20	>0.5000	-0.23	>0.5000	0.7655
14. $(\text{avgpr10} > \text{time})$ or $(1 < \text{quant})$	60.07	45.68	-0.528	-2.816	-2.20	>0.5000	-0.23	>0.5000	0.7655
15. $(\text{quant2} > 1)$ or $(\text{minpr20} > \text{bestbid})$	60.07	46.36	-1.880	-4.136	-1.82	>0.5000	-0.82	>0.5000	0.6765
16. $(\text{quant1} \geq \text{avgpr5})$ or $(\text{lagpr2} > \text{time1})$ or $(5.82 \geq \text{bidcount2})$	60.07	46.23	-1.539	-3.308	-1.94	>0.5000	-0.74	>0.5000	0.7015
17. $(\text{quant2} > \text{time} - \frac{0.892}{\text{minpr10}})$ or $(\text{maxpr5} < \text{quant})$	60.07	45.68	-0.528	-2.816	-2.20	>0.5000	-0.23	>0.5000	0.7655
18. $(\frac{5.76}{\min(2.78, \text{avgret20}) \cdot \text{bestbid}} > \text{bidcount2})$ or $(\text{quant1} > \text{bestbid1})$	59.36	45.95	-2.906	-5.196	-2.05	>0.5000	-1.26	>0.5000	0.7285
19. $(\text{time2} + \text{maxpr10} - \frac{\text{maxpr10}}{8.02} \leq 8.81 \cdot \text{bestbidq1} + \text{depthbid1})$ and $(\text{avgpr20} < \text{quant})$	59.01	46.23	-0.012	-2.428	-1.97	>0.5000	-0.01	>0.5000	0.7015
20. $(\text{quant} \geq \text{lagret2} + \min(\frac{\text{offcount2}}{(\text{offcount}-\text{price})\cdot 6.97}, \max(\text{lagret1}, \text{time1}))$ $(7.35 \leq \text{offcount})$	58.66	45.95	-1.624	-3.783	-2.11	>0.5000	-0.69	>0.5000	0.7285
21. Average	59.72	46.36	0.222	-2.161	-1.83	>0.5000	0.09	0.4641	0.6765

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WARWICK
BUSINESS SCHOOL

$k = 0.005$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $(1 < \text{bestbidq1})$ and $(\text{bestoffq} \geq \text{avgret20} + \text{quant2})$	85.19	47.27	0.430	0.156	-0.46	>0.5000	0.24	0.4052	0.5885
2. $(\text{quant} < \text{bestoffq})$ and $(\text{bestbidq} \leq \min\{\text{bestbidq2}, \text{depthbid1}, \text{bestoffq1}\})$	85.19	51.82	-0.145	-0.450	0.65	0.2578	-0.06	>0.5000	0.3325
3. $(\text{quant2} < \text{bestoffq})$ and $((\text{liqbid} \geq \text{bestbid1})$ or $(\text{bestbid1} < \text{bestbidq1}))$	85.19	50.00	1.522	1.184	0.21	0.4168	0.73	0.2327	0.4360
4. $((\text{bestbid2} - \text{maxret10}) \cdot (\text{bidcount2} + \text{bestbidq}) < \text{offcount})$ and $(\text{bestoffq} > \text{quant1})$	85.19	53.64	2.272	1.959	0.99	0.1611	0.98	0.1635	0.2545
5. $\{\text{liqoff2} < 0.14 \cdot \text{offcount2} \cdot \min\{\text{liqbid2}, \min\{\text{bestbid1}, \text{time7}, 4.15\}\}\}$ and $\{\text{quant2} < \text{bestoffq}\}$	85.19	53.64	0.709	0.307	1.00	0.1587	0.31	0.3783	0.2545
6. $(\text{avgret5} < \text{bestbidq1})$ and $(\max\{-\max\{\text{bestoffq}, (\text{avgret5} - \text{liqbid1}) \cdot \text{quant2}\}, \text{bestoffq} + (\text{maxpr5} - \text{quant2} \cdot \text{quant2}) > \text{maxpr10})$	85.19	52.73	2.258	1.877	0.79	0.2148	1.02	0.1539	0.2935
7. $((\text{liqoff2} < \text{liqbid2})$ or $(\text{avgpr20} > \text{avgpr10}))$ and $(\max\{\text{avgpr20}, 3.5433 - \min\{\text{bestoffq}, 2.0178\}\} < \text{bestbidq1})$	85.19	50.91	1.445	1.127	0.41	0.3409	0.64	0.2611	0.3775
8. $((\text{liqoff2} < \text{liqbid2})$ or $(\text{avgpr20} > \text{avgpr10}))$ and $(\text{maxpr5} < \text{bestbidq1})$	81.48	50.91	0.895	0.580	0.41	0.3409	0.40	0.3446	0.3775
9. $(\text{bestbidq2} \leq 6)$ and $(\text{quant1} < \text{bestoffq} \cdot \text{minret10})$	81.48	49.09	-0.314	-0.672	0.00	0.5000	-0.13	>0.5000	0.4905
10. $(\text{quant} < \text{bestoffq})$ and $(\text{bestbidq} \leq \text{bestoffq})$	81.48	52.73	0.934	0.558	0.79	0.2148	0.41	0.3409	0.2935
11. $(\text{bestoffq} > 3.8 - \min\{1.15, 3.5 - \text{quant1}\})$ or $(2 > \text{bidcount2})$	81.48	51.82	0.097	-0.296	0.58	0.2810	0.05	0.4801	0.3325
12. $(\text{depthoff2} \leq \text{bestbidq2})$ or $(\text{bestoffq} - \text{avgret10} > 1.35)$ or $(\text{depthoff2} \leq \text{avgpr20})$	81.48	54.55	0.936	0.550	1.16	0.1230	0.40	0.3446	0.2205
13. $(3 \geq \text{bestbidq})$ and $(\text{quant1} < \text{bestoffq})$	81.48	52.73	1.072	0.722	0.79	0.2148	0.47	0.3192	0.2935
14. $(\text{quant2} < \text{bestbidq})$ and $(\text{minret5} < \text{bestoffq2})$	81.48	50.91	0.308	-0.079	0.38	0.3520	0.13	0.4483	0.3775
15. $(\text{avgret10} \leq \text{quant2})$ and $(\text{quant2} < \text{bestoffq})$	81.48	53.64	2.646	2.270	0.99	0.1611	1.11	0.1335	0.2545
16. $(\text{bestoffq} \geq \text{liqoff})$ and $(\text{bestoffq} > \text{quant1} + \text{minret5})$	81.48	50.91	0.430	0.056	0.38	0.3520	0.18	0.4286	0.3775
17. $(\text{bestoffq} > \max\{\text{quant}, 2\})$	77.78	53.64	0.980	0.597	0.98	0.1635	0.42	0.3372	0.2545
18. $\text{bestoffq} > \text{bestbidq2}$	77.78	57.27	1.761	1.375	1.74	0.0409	0.74	0.2296	0.1425
19. $(\text{lagpr2} > \text{price})$ or $(5.69 - 2.866 \cdot \text{bestoffq} > \text{maxret10})$	77.78	55.45	3.405	3.295	2.50	0.0062	3.11	0.0009	0.1925
20. $(\text{maxret10} > \text{depthoff2})$ or $|(3 \leq \text{bestoffq})$	77.78	54.55	-0.040	-0.419	1.16	0.1230	-0.01	>0.5000	0.2205
21. **Average**	85.19	47.27	-0.968	-1.337	-0.38	>0.5000	-0.41	>0.5000	0.5885

Trading rules based on the all order book information. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives a buy signal if more than 9 of best 19 rules give a buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0.01$

Technical rules	In-sam. DC, %	Out-of-sam. DC, %	Returns, $\theta = 0$	Returns, $\theta = 10^{-4}$	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (offcount > 6) and (offcount2 ≤ 8)	100.00	50.00	-0.915	-0.935	0.07	0.4721	-3.68	>0.5000	0.4315
2. (max{time · 2.5, maxret20} < $\frac{\text{offcount2}+8.4}{\text{avgret10}}$) and (offcount < 9)	100.00	50.00	-0.128	-0.141	-1.02	>0.5000	-0.73	>0.5000	0.4315
3. (liqoff2 − offcount1 > −8.9) and (bidcount2 > 7)	100.00	52.38	0.149	0.122	0.10	0.4602	0.61	0.2709	0.3025
4. offcount = offcount1	100.00	50.00	-0.025	-0.212	-0.09	>0.5000	-0.01	>0.5000	0.4315
5. (bestbid > bestbid2) or ((quant2 ≥ lagret1) and (lagpr2 ≥ bestoffq1))	100.00	38.10	-0.806	-0.905	-1.65	>0.5000	-0.43	>0.5000	0.9325
6. (offcount < 9) and (time < time1)	100.00	47.62	-0.312	-0.385	-0.28	>0.5000	-0.40	>0.5000	0.5725
7. time1 > avgpr20 · time	100.00	35.71	-2.670	-2.806	-1.97	>0.5000	-1.20	>0.5000	0.9655
8. (bestbid > bestbid2) or (bestbid > avgpr5)	100.00	28.57	-4.328	-4.475	-3.04	>0.5000	-1.87	>0.5000	>0.999
9. bestoff2 = bestoff	100.00	52.38	0.178	0.104	0.59	0.2776	0.23	0.4090	0.3025
10. ($|\frac{\text{avgpr10}}{6.3\cdot(\text{quant2}-\text{bestbidq1})+3.52}| \leq$ maxpr20) or (bestoff2 > bestoffq1)	100.00	47.62	1.264	1.163	-0.22	>0.5000	0.58	0.2810	0.5725
11. (quant < $\frac{\text{depthbid1}}{3.8}$) and (avgpr10 < bestbid1)	100.00	50.00	0.072	0.012	0.20	0.4207	0.05	0.4801	0.4315
12. (2.52 ≤ bestoffq) or (max{liqoff2, bestbid1} > maxpr5)	100.00	59.52	1.817	1.702	1.59	0.0559	0.78	0.2177	0.0465
13. bestoffq1 − liqbid1 < bestoffq	100.00	54.76	2.680	2.591	1.13	0.1292	2.33	0.0099	0.1915
14. (bestoff2 ≤ bestoff) or (liqoff2 > avgret10)	100.00	40.48	-1.781	-1.931	-1.22	>0.5000	-0.76	>0.5000	0.8755
15. 8 ≥ offcount2	83.33	45.24	-0.823	-0.869	-0.65	>0.5000	-0.73	>0.5000	0.6885
16. lagret2 > time	83.33	50.00	-0.099	-0.145	0.10	0.4602	-0.04	>0.5000	0.4315
17. (time ≤ avgret10) or (0.23 > liqoff2)	83.33	50.00	-0.099	-0.145	0.10	0.4602	-0.04	>0.5000	0.4315
18. bestoffq1 ≤ minpr10	83.33	45.24	0.846	0.732	-0.55	>0.5000	0.36	0.3594	0.6885
19. minpr5 > min{lagpr1, bestbid}	83.33	57.14	3.741	3.582	0.99	0.1611	1.67	0.0475	0.1065
20. (depthoff2 ≤ 6.54) or (offcount2 < maxpr20 · 5.37)	83.33	45.24	-0.823	-0.869	-0.65	>0.5000	-0.73	>0.5000	0.6885
21. **Average**	**100.00**	**47.62**	**-0.985**	**-1.024**	**-0.77**	**>0.5000**	**-2.27**	**>0.5000**	**0.5725**

Trading rules based on the all order book information. The fitness function is the percentage of the correct in-sample predictions of the exchange rate directional changes. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives a buy signal if more than 9 of best 19 rules give a buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0$

Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $(\text{ret}^2 \cdot \text{maxret20} < \text{lagret1} \cdot \text{maxret5})$ or $(\text{ret} \cdot \text{maxret10} < \text{lagret1} \cdot \text{maxret5})$	6.562	8.689	8.905	51.48	2.15	0.0158	3.67	0.0001	<0.001
2. $(\text{minret20} < \text{avgret20})$ and $(\text{ret} < \text{lagret2})$	6.347	9.092	-10.102	51.42	2.05	0.0202	3.81	0.0001	<0.001
3. $\text{ret} < \text{lagret2}$	6.347	9.092	-10.102	51.42	2.05	0.0202	3.81	0.0001	<0.001
4. $(\text{lagpr1} > \text{minpr5})$ and $(\text{lagret2} > \text{ret})$	6.321	9.359	-9.966	51.54	2.22	0.0132	2.20	0.0139	<0.001
5. $(\text{ret} < \text{lagret2})$ or $(\text{maxret20} = \text{lagret2})$	6.314	9.186	-10.036	51.52	2.19	0.0143	3.85	0.0001	<0.001
6. $(\text{lagret2} = \text{maxret10})$ or $(\text{lagret1} > \text{ret})$	6.222	9.631	-10.688	50.88	1.28	0.1003	4.08	<0.0001	<0.001
7. $(\text{ret} < \text{lagret1})$ or $(\text{ret} < \text{lagret2})$	6.158	9.935	-9.190	51.63	2.44	0.0073	4.32	<0.0001	<0.001
8. $(\text{avgret5} > \text{ret})$ or $(\text{lagret2} \geq \text{ret})$	5.996	8.547	-9.362	51.40	2.06	0.0197	3.66	0.0001	0.0015
9. $(\text{lagpr1} \cdot \text{lagret1} > \text{price})$ and $(\text{price} \leq \text{maxpr5})$	5.861	8.806	-12.084	51.12	1.61	0.0537	3.70	0.0001	0.0015
10. $\text{ret} \leq \text{lagret1}$	5.861	8.806	-12.084	51.12	1.61	0.0537	3.70	0.0001	0.0015
11. $(\text{avgret5} > \text{ret})$ or $(\text{avgpr10} = \text{avgpr5})$	5.861	7.153	-11.074	51.10	1.58	0.0571	3.03	0.0012	0.0115
12. $\text{ret} \leq \text{avgret5}$	5.771	7.467	-10.814	50.96	1.39	0.0823	3.15	0.0008	0.0065
13. $\text{lagpr1} \cdot \text{avgret5} > \text{price}$	5.771	7.465	-10.814	50.96	1.39	0.0823	3.15	0.0008	0.0065
14. $(\text{lagpr1} > \text{minpr5})$ and $(\text{maxret10} > \text{ret})$	5.658	9.868	-5.755	51.67	2.75	0.0030	4.75	<0.0001	<0.001
15. $\text{maxret20} \cdot \text{ret} < \text{maxret10}$	5.416	9.460	-5.930	50.62	0.93	0.1762	4.10	<0.0001	<0.001
16. $(\text{maxret20} = \text{lagret2})$ or $(\text{ret} < \text{avgret10})$ or $(\text{avgpr20} = \text{minpr10})$	5.343	8.593	-9.228	50.92	1.33	0.0918	3.61	0.0002	0.0015
17. $(\text{price} = \text{avgpr20})$ or $(\text{avgret5} = \text{avgret10})$ or $(\text{price} \leq \text{lagpr1})$	5.169	8.534	8.925	50.54	0.78	0.2177	3.59	0.0002	0.0015
18. $(\text{minret5} = \text{ret})$ and $(\text{price} < \text{lagpr2})$	5.113	6.198	-5.470	49.94	-0.06	>0.5000	3.21	0.0007	0.0385
19. $\text{price} \leq \text{lagpr1}$	5.054	8.444	-8.934	50.50	0.72	0.2358	3.57	0.0002	0.0025
20. $(\text{maxpr10} < \text{price})$ or $(\text{ret} = \text{minret5})$	5.021	5.422	-8.751	50.81	1.34	0.0901	2.60	0.0047	0.0795
21. Average	**5.654**	**8.327**	**-10.267**	**51.00**	**1.44**	**0.0749**	**3.51**	**0.0002**	**0.0025**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.0005$

Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (maxpr10 · minret20 < avgpr5) and (maxret20 · minret20 ≤ lagret2)	4.569	6.233	2.477	52.62	1.89	0.0294	2.74	0.0031	0.0065
2. (maxpr5 > minpr10) and (lagret1 > maxret20 · minret20)	4.017	6.407	2.092	51.62	1.33	0.0918	2.73	0.0032	0.0065
3. (ret ≤ minret10) or (lagret1 ≤ minret20) or (avgret5 = minret20)	3.447	4.934	0.224	52.15	1.52	0.0643	2.19	0.0143	0.0155
4. (ret < minret10) or (lagret1 = min{avgret20, minret10})	3.415	4.938	0.227	52.15	1.52	0.0643	2.20	0.0139	0.0155
5. (ret ≤ minret10) or (lagret1 ≤ minret20)	3.372	4.076	-0.731	50.94	0.51	0.3050	1.87	0.0307	0.0205
6. (price < maxpr5) or (maxret20 > maxret10)	3.325	5.083	1.415	50.54	0.86	0.1949	2.44	0.0073	0.0135
7. (ret · maxret20 ≤ lagret1) and (price = minpr10)	3.304	3.335	0.884	51.55	0.90	0.1841	3.39	0.0003	0.0305
8. price · minret20 ≤ avgpr20	3.273	5.098	2.757	50.61	0.97	0.1660	2.51	0.0060	0.0135
9. (lagpr1 = minpr20) or (ret = minret10)	3.263	3.289	-1.315	50.67	0.32	0.3745	1.49	0.0681	0.0305
10. (ret < maxret10) or (maxpr5 > min{price, maxpr10})	3.184	4.895	1.937	49.66	0.33	0.3707	2.79	0.0026	0.0155
11. (price < maxret10) or (ret < maxret10)	2.104	4.231	1.930	49.60	0.38	0.3520	2.68	0.0037	0.0205
12. max{maxpr5, price − avgret20 + minret10} > price	3.155	7.652	1.930	51.35	1.19	0.1770	3.27	0.0005	0.0015
13. price < maxpr5	3.124	7.333	2.761	51.35	1.19	0.1770	3.13	0.0009	0.0025
14. (ret ≤ minret10) and (avgret5 · lagret2 > ret)	3.098	6.425	1.885	52.02	1.35	0.0885	3.14	0.0008	0.0065
15. ((lagret2 ≤ maxret20) and (avgret5 = maxret5)) or ((price ≤ avgret5 · avgpr20) and (minpr10 = minpr20))	3.000	11.058	7.669	51.14	0.77	0.2206	4.64	<0.0001	<0.001
16. price + minpr20 − avgpr20 < lagpr2	2.932	5.003	2.534	51.28	2.18	0.0146	3.09	0.0010	0.0145
17. (ret < maxret10) or (price < max{lagpr2, max{avgpr5, minpr20}})	2.926	4.488	1.245	50.07	0.67	0.2514	2.43	0.0075	0.0175
18. min{ret, avgret5} ≤ minret10	2.883	6.127	1.492	51.62	1.01	0.1562	2.92	0.0018	0.0075
19. (ret ≤ minret10) or (avgret5 = minret20)	2.858	6.141	1.532	51.62	1.01	0.1562	2.95	0.0018	0.0075
20. ret ≤ minret10	2.821	6.172	1.575	51.68	1.07	0.1423	2.96	0.0015	0.0065
21. Average	**3.460**	**6.676**	**1.833**	**51.75**	**1.31**	**0.0951**	**2.84**	**0.0023**	**0.0065**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

$k = 0.001$

Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (maxpr10 − avgret5 + maxret5 ≤ maxpr20) or (maxpr10 − avgret5 + minret10 ≤ avgpr20)	3.781	6.049	4.484	51.92	0.98	0.1635	2.61	0.0045	0.0035
2. (minpr10 = lagpr1) or (minret20 ≥ ret)	3.574	4.581	2.633	52.88	1.51	0.0655	2.29	0.0110	0.0115
3. (maxret10 · avgpr20 ≥ maxpr5) or (avgpr5 = lagpr2) or (avgpr5 = avgpr10)	3.567	1.473	-0.077	51.10	0.70	0.2420	0.64	0.2611	0.0865
4. avgpr20² · lagpr2 > minpr5 · maxpr5²	3.465	6.909	5.191	53.16	1.66	0.0485	2.97	0.0015	<0.001
5. (price = minpr20) or (min{lagpr1, avgpr5} = minpr20)	3.452	6.013	4.170	52.61	1.35	0.0885	2.62	0.0044	0.0035
6. (avgpr10 = avgpr5) or (min{price, lagpr1} = minpr20)	3.400	5.339	3.494	51.92	0.98	0.1635	2.32	0.0102	0.0065
7. (min{price, lagpr1} = avgpr10) or (min{price, lagpr1} = minpr20)	3.287	6.012	4.170	52.61	1.35	0.0885	2.61	0.0045	0.0035
8. (minret20 = lagret1) or (price · maxret5 ≤ avgpr10)	3.282	2.001	0.061	51.10	0.54	0.2946	0.88	0.1894	0.0645
9. (lagret1 = minret10) or (ret = minret10)	3.264	4.346	2.164	53.16	1.65	0.0495	2.01	0.0222	0.0125
10. (avgret10 < avgret20) or (price = minpr20)	3.262	5.390	3.379	52.34	1.41	0.0793	2.39	0.0084	0.0065
11. (lagret1 = minret10) or (ret = minret10)	3.252	6.350	4.043	55.63	3.08	0.0010	2.93	0.0017	0.0025
12. (lagpr2 = avgpr5) or (minret10 ≥ ret)	3.204	6.251	3.911	54.26	2.32	0.0102	2.93	0.0017	0.0025
13. (avgret10 < avgret20) or (min{avgret10, lagret1² · ret} ≤ avgret20)	3.029	1.287	2.570	51.10	0.80	0.2119	2.08	0.0188	0.0995
14. (lagret1 = minret10) or (ret = minret10)	3.006	5.397	2.973	54.26	2.26	0.0119	2.39	0.0084	0.0035
15. minret10 = min{ret, lagret1}	3.006	5.397	2.973	54.26	2.26	0.0119	2.39	0.0084	0.0035
16. (minpr10 = minpr20) and (ret ≤ min{minret10, $\frac{avgret5}{lagret1}$})	2.890	5.874	4.235	52.06	1.05	0.1469	3.20	0.0007	0.0035
17. (ret ≤ minret10) and (minpr10 = minpr5)	2.864	6.172	4.383	53.43	1.94	0.0262	3.24	0.0006	0.0035
18. (minret10 ≥ ret) and (price ≤ avgpr10)	2.839	6.602	4.694	53.98	2.27	0.0116	3.33	0.0004	0.0015
19. (avgret10 ≤ avgret20) or (ret ≤ minret10)	2.791	3.068	0.960	50.55	0.44	0.3300	1.38	0.0838	0.0305
20. ret ≤ minret10	2.645	6.387	4.225	53.30	1.78	0.0375	3.13	0.0009	0.0025
21. Average	**3.555**	**4.150**	**2.190**	**52.75**	**1.42**	**0.0778**	**1.88**	**0.0301**	**0.0165**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0.005$

	Technical rules	In-sam., Ret., %	Out-of-sam. Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	(minret10 · 1.637268 ≥ avgpr5) or (minret20 + maxret20 < 2 · lagret2)	3.292	0.644	0.550	53.77	1.49	0.0681	0.53	0.2981	0.1555
2.	(min{minret20, ret} = lagret1) or (minret20 = ret)	2.918	4.085	3.711	60.38	2.21	0.0136	1.76	0.0392	0.0145
3.	(minpr10 ≥ lagpr1) or ((avgret20 ≤ avgret5) and (lagpr1 ≥ price))	2.635	-1.315	-1.656	44.34	-1.20	>0.5000	-0.58	>0.5000	0.3005
4.	(avgret20 ≤ avgret5) and (lagret1 ≥ avgret20)	2.293	-2.298	-2.591	47.17	-0.61	>0.5000	-1.07	>0.5000	0.3985
5.	max{$\frac{avgpr10 \cdot lagret2}{avgpr5}$, avgpr5} > lagpr2	2.070	2.784	2.415	60.38	2.33	0.0099	1.37	0.0853	0.0325
6.	ret · maxret20 < lagret1	1.994	7.952	7.543	68.87	4.64	<0.0001	3.96	<0.0001	0.0015
7.	ret ≤ minret5	1.992	9.634	9.145	72.64	5.44	<0.0001	4.19	<0.0001	0.0015
8.	(maxpr5 ≥ maxpr20) and (maxpr5 > price)	1.964	3.718	3.497	56.60	1.73	0.0418	2.08	0.0188	0.0175
9.	(lagret2 > minret5) and (price ≥ $\frac{minpr20}{avgpr5}$)	1.934	-5.758	-6.059	35.85	-3.06	>0.5000	-2.60	>0.5000	0.7185
10.	(lagpr1 < avgpr20) or (max{avgpr20, minpr5} ≥ price)	1.813	4.914	4.628	59.43	2.07	0.0192	2.27	0.0116	0.0085
11.	price ≤ max{avgpr20, lagpr2}	1.813	7.812	7.367	66.98	3.72	0.0001	3.32	0.0005	0.0015
12.	(price ≤ max{lagpr1, lagpr2})or(maxpr5 ≤ lagpr1)	1.813	8.690	8.198	69.81	4.48	<0.0001	3.71	0.0001	0.0015
13.	maxpr5 > price	1.813	8.212	7.751	67.92	4.01	<0.0001	3.54	0.0002	0.0015
14.	avgret20 < avgret5	1.635	-0.105	-0.418	48.11	-0.39	>0.5000	-0.05	>0.5000	0.1935
15.	(minpr5 > price) or (lagpr1 ≤ avgpr20)	1.497	4.905	4.604	59.43	2.04	0.0207	2.20	0.0139	0.0085
16.	(minpr10 = minpr20) and (price ≤ minpr20 · maxret20)	1.491	7.862	7.410	67.92	3.96	<0.0001	3.32	0.0005	0.0015
17.	min{price, lagpr1} ≤ avgpr20	1.491	4.914	4.628	59.43	2.07	0.0192	2.27	0.0116	0.0085
18.	$\frac{avgpr10}{lagpr2 - price \cdot lagret2}$ > 0.6707	1.472	6.690	6.229	67.92	3.96	<0.0001	2.84	0.0023	0.0025
19.	(lagret2 = maxret5) or (lagpr2 > price)	1.472	7.983	7.537	67.92	3.96	<0.0001	3.37	0.0004	0.0015
20.	price < lagpr2	1.472	8.148	7.602	67.92	3.95	<0.0001	3.39	0.0003	0.0015
21.	**Average**	**1.813**	**8.690**	**8.198**	**69.81**	**4.48**	**<0.0001**	**3.71**	**0.0001**	**0.0015**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0.01$

Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. avgpr20 < 1.6345	1.707	-1.062	-1.095	48.72	-0.05	>0.5000	-1.31	>0.5000	0.3635
2. (minpr20 ≥ price) or (avgpr5 ≥ avgpr10)	1.707	3.503	3.399	56.41	1.21	0.1131	3.16	0.0008	0.0145
3. (maxpr5 < 1.6422) and (lagpr1 < maxpr5)	1.645	-2.457	-2.548	41.03	-1.18	>0.5000	-1.79	>0.5000	0.5675
4. (lagret2 ≥ 1) and (lagret2 · avgret20 ≥ avgret10)	1.645	1.827	1.705	53.85	0.55	0.2912	0.86	0.1949	0.0575
5. maxpr20 > minret10 > avgpr10 · maxret20	1.645	0.318	0.238	53.85	0.49	0.3121	0.26	0.3974	0.1625
6. avgret20 ≤ min{lagret1, lagret2}	1.085	-1.234	-1.346	51.28	0.09	0.4641	-0.60	>0.5000	0.3895
7. maxpr10 < 1.6394	1.085	1.166	1.106	58.97	1.24	0.1075	0.83	0.2033	0.0925
8. min{avgret20, maxret5} ≤ lagret2	1.078	-2.909	-3.026	41.03	-1.13	>0.5000	-1.31	>0.5000	0.6025
9. lagret2 > avgret20	1.078	-2.909	-3.026	41.03	-1.13	>0.5000	-1.31	>0.5000	0.6025
10. (minret20 < minret5) and (avgpr20 ≤ lagpr2)	1.023	-3.189	-3.305	33.33	-2.62	>0.5000	-1.68	>0.5000	0.6445
11. (maxpr20 > lagpr1) and (avgret20 > 1)	1.023	0.071	-0.083	38.46	-1.52	>0.5000	0.04	0.4840	0.1955
12. minret20 · lagpr1 > lagpr2	1.023	-0.958	-0.991	48.72	-0.56	>0.5000	-3.31	>0.5000	0.3505
13. minpr20 < minpr5	1.023	-2.846	-2.955	33.33	-2.34	>0.5000	-1.39	>0.5000	0.5975
14. (lagret2 < lagret1) and (lagret2 < ret)	1.023	-0.146	-1.506	46.15	-1.03	>0.5000	-5.25	>0.5000	0.2475
15. lagret1 < maxret5	1.016	-2.186	-2.284	35.90	-2.27	>0.5000	-1.29	>0.5000	0.5325
16. lagpr1 < maxpr5	1.016	-1.279	-1.351	41.03	-1.52	>0.5000	-1.00	>0.5000	0.3965
17. ret > minret5	1.016	-5.612	-5.781	23.08	-4.01	>0.5000	-2.77	>0.5000	0.8705
18. 2.6339 > price + maxret20	0.832	7.942	7.777	79.49	5.04	>0.0001	5.27	>0.0001	<0.001
19. price = minpr20	0.832	8.108	7.899	82.05	5.25	>0.0001	3.56	0.0002	<0.001
20. minpr20 > price · avgret5	0.770	5.530	5.383	74.36	3.82	0.0001	2.37	0.0089	0.0045
21. Average	**1.645**	**1.447**	**1.359**	**51.28**	**0.20**	**0.4207**	**0.65**	**0.2578**	**0.0745**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

$k = 0$

Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (lagret2 > ret) and (minpr5 $\leq$ bestbid)	8.404	12.256	-0.476	53.76	5.75	<0.0001	5.18	<0.0001	0.0035
2. (12.13 · price $\geq$ time1) and (price $\leq$ bestoff)	7.984	10.097	-2.631	53.26	5.43	<0.0001	4.76	<0.0001	0.0035
3. bestbid > min{avgpr20, price, bidcount1}	7.675	5.540	-3.446	56.76	9.96	<0.0001	2.30	0.0107	0.0205
4. (max{avgpr20, price} $\leq$ bestoff) or (bestbidq = maxret5)	7.534	7.326	-2.231	57.43	11.06	<0.0001	3.02	0.0013	0.0105
5. (bidcount2 $\geq$ time1) and (price $\leq$ bestoff)	7.436	7.571	-6.112	53.16	4.98	<0.0001	3.39	0.0003	0.0085
6. (bestoff1 = maxpr20) or (ret $\geq$ lagret2)	7.272	9.669	-8.193	51.78	2.63	0.0043	3.98	<0.0001	0.0045
7. (ret < lagret2) or (max{min{$\frac{1.91 - 7.2 \cdot maxpr20}{avgret10 = 0.097}$, avgret10}, ret} < lagret1)	6.851	11.624	-8.112	51.57	2.34	0.0096	4.78	<0.0001	0.0035
8. (ret $\leq$ lagret2) or (ret < lagret1)	6.773	10.730	-8.044	51.59	2.41	0.0080	4.50	<0.0001	0.0035
9. price $\leq$ bestoff	6.768	9.490	4.102	54.89	13.15	<0.0001	7.61	<0.0001	0.0045
10. bestbid $\geq$ price	6.526	9.258	-4.932	51.05	1.61	0.05367	3.84	0.0001	0.0045
11. (avgret10 > depthbid2) or (((offcount2 > offcount1)or(time $\leq$ 2.08 · lagpr2))and(ret $\leq$ min{bestbidq2, avgret10}))	6.465	1.618	-10.178	52.14	3.66	0.0001	0.83	0.2033	0.1375
12. (9.31 − $\frac{8.79}{time}$ > 8.79) and (price $\leq$ bestoff1)	6.357	0.117	-13.384	51.80	2.63	0.0043	0.05	0.4801	0.2505
13. ret $\leq$ lagret2	6.229	10.213	-9.154	51.14	1.65	0.0495	4.10	<0.0001	0.0035
14. ret $\leq$ avgret5	5.771	8.439	-10.006	50.97	1.40	0.0808	3.41	0.0003	0.0075
15. (min{depthoff, ret} = minret5) or (depthbid1 $\leq$ 2.4)	5.453	5.948	-8.345	50.91	1.48	0.0694	2.73	0.0032	0.0185
16. ((minpr5 = price) or (depthbid2 $\leq$ 5.01) or (bestbid = price)) and (bestoff1 + 7.61 > min{time, depthbid})	5.296	2.101	-8.594	49.32	-1.14	>0.5000	1.00	0.1587	0.1175
17. (maxpr5 $\leq$ bestoff) or (lagret1 = maxret20)	5.233	7.786	-3.993	57.18	10.49	<0.0001	3.16	0.0008	0.0075
18. (bestoffq1 > ret) and (bestoff $\geq$ lagpr2) and (offcount2 $\geq$ 1.51 · (0.16 + bestbidq1))	5.036	5.803	-10.145	53.24	4.75	<0.0001	2.40	0.0082	0.0195
19. (time1 < $\frac{6.54 \cdot price}{maxpr10 - [4.71 - bestbid1 - bestbid]}$ + 7.61) · (bestoffq1 − 5.55)) or (price $\leq$ bestoff1)	5.017	7.777	-1.426	51.45	2.84	0.0023	4.29	<0.0001	0.0075
20. (depthbid1 < 4.83 − ret) or (minret10 = ret)	5.011	8.972	-1.041	50.86	1.64	0.0505	4.85	<0.0001	0.0095
21. Average	**9.165**	**11.830**	**-8.481**	**53.37**	**4.95**	**<0.0001**	**4.79**	**<0.0001**	**0.0035**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

$k = 0.0005$

Technical rules	In-sam., Ret., %	Out-of-sam. Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $(bestoffq - \frac{offcount2}{avgret2-5.5} \geq 3.19)$ and $((bestbids2 - 2.16 \geq avgpr20)$ or $(\frac{3.775+max\{12.57,bidcount1\}}{bidcount} < bestoffq1))$	4.945	-1.098	-5.057	48.89	-1.08	>0.5000	-0.47	>0.5000	0.2825
2. $((3.7 \cdot min\{2.4, 7.7 - time, 9.07 + minpr20 + minret20\} > avgret20)$ or $(liqoff2 \geq liqoff \cdot minpr20))$ and $(bestoff1 \geq price)$	4.753	4.586	0.459	50.77	0.38	0.3520	1.97	0.0244	0.0075
3. $(bestoff > price)$ or $(price = bestbid1)$	4.513	5.334	1.076	52.52	2.36	0.0091	2.27	0.0116	0.0055
4. $(min\{\frac{bestoffq}{avgret}, bestoffq1\} > minpr5)$ and $(offcount1 > 9)$	4.504	-2.071	-5.678	48.02	-1.83	>0.5000	-0.90	>0.5000	0.3855
5. $(min\{bidcount2, \frac{4.55}{avgpr5}\} \leq 2.655)$ or $(price \leq bestbid)$ or $(depthbid1 < max\{\frac{8.028}{avgpr5}, bestbidq1\})$	4.368	7.155	2.639	53.40	2.48	0.066	3.02	0.0013	0.0035
6. $bestbid > min\{bestoff1, price\}$	4.330	9.725	4.632	54.20	3.22	0.0006	3.92	<0.0001	<0.001
7. $(\frac{20.26}{offcount} \leq bestoffq)$ and $(\frac{34.54}{offcount} < min\{5.04, bestoffq1\})$	4.165	-1.897	-5.246	48.15	-1.49	>0.5000	-0.81	>0.5000	0.3685
8. $(1.8 < min\{bestoffq1, bestoffiq\})$ and $(depthoff > bidcount2)$	4.094	-1.642	-5.442	48.15	-1.66	>0.5000	-0.71	>0.5000	0.3325
9. $(min\{bestoffq - avgret5, bestoffiq1\} \geq avgret5)$ and $(7.42 \leq offcount1 - \frac{bestbid}{avgpr5})$	4.091	-1.840	-5.632	47.34	-2.28	>0.5000	-0.79	>0.5000	0.3645
10. $((maxpr10 > price)$ and $(avgpr20 - time1 \geq maxpr10))$ or $(\frac{minret5-minpr10}{time} > max\{avgpr20 \cdot time1, 3.073\})$	4.075	2.132	-2.219	49.50	-0.35	>0.5000	0.89	0.1867	0.0635
11. $(price < bestoff1)$ or $(min\{8.8, offcount\} > depthoff2)$	4.017	6.449	2.829	50.50	0.94	0.2514	3.01	0.0013	0.0035
12. $(liqoff2 \leq 5.14)$ and $(((maxpr5 < bestoff1)$ or $(price = minpr10))$ and $(bestbid > minpr10))$	3.969	11.281	7.842	56.42	5.72	<0.0001	5.91	<0.0001	<0.001
13. $(bestbid < bestoffq1)$ and $(quant2 < depthoff1 - bidcount1 \cdot 0.73 - time)$	3.953	-1.263	-4.937	48.62	-1.19	>0.5000	-0.54	>0.5000	0.3015
14. $(quant1 > 2.8)$ or $(bestoffq > max\{\frac{4.5}{bestbidq2}, quant1\})$	3.938	-0.801	-5.474	48.69	-1.03	>0.5000	-0.34	>0.5000	0.2495
15. $bestbid \geq price$	3.889	10.072	5.440	53.60	2.70	0.0035	4.21	<0.0001	<0.001
16. $(quant2 < bestoffiq)$ or $(min\{min\{7.6, 13.73 - ret - depthbid2\} + \frac{bestoffiq+maxret10}{liqoff2+3}, depthbid\} + lagpr1 > 2 + quant)$	3.745	-1.413	-5.851	49.56	-0.36	>0.5000	-0.60	>0.5000	0.3195
17. $(quant < bestoffq)$ and $(offcount > 9)$	3.579	-0.368	-4.663	49.90	-0.15	>0.5000	-0.15	>0.5000	0.2035
18. $(9.82 < max\{min\{max\{7.55, 9.33 - bestoffq1 - bestbid2\}, offcount\}, minret10 \cdot avgpr5\})$ and $(8.79 < bidcount)$	3.517	-0.786	-4.529	49.16	-0.74	>0.5000	-0.33	>0.5000	0.2485
19. $(quant2 < bestoffq)$ and $(bestoffq1 > 1)$	3.405	0.230	-3.033	50.24	-0.24	>0.5000	0.12	0.4522	0.1595
20. $(bestoffq > ret)$ and $(time1 > ret)$	3.359	1.998	-2.645	50.77	0.77	0.2206	0.89	0.1977	0.0725
21. Average	**5.518**	**1.173**	**-2.606**	**49.76**	**-0.40**	**>0.5000**	**0.51**	**0.3050**	**0.0795**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.001$

	Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, θ = 0	O-of-s, Ret., θ = 10⁻⁴	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	$((depthoff2 > max\{8.62, bidcount1\} - minret5)$ and $(quant > liqbid)$ and $(price < bestbid1))$ or $((depthoff2 > max\{8.62, bidcount1\} + 0.46)$ and $(16.19 + liqbid2 > offcount))$	4.843	2.008	0.476	50.62	0.67	0.2514	0.87	0.1922	0.0725
2.	$((lagret1 \leq minpr20 \cdot quant \cdot minret10 - 2.2713)$ and $(3.89 < time1 + minret20))$ or $(9 < bestbidq)$	4.561	-2.606	-2.162	49.25	-0.58	>0.5000	-0.04	>0.5000	0.4845
3.	$(bestoff \geq price)$ and $(liqbid + minret10 \leq quant2)$	4.076	4.967	3.143	53.09	2.21	0.0136	2.32	0.0102	0.0155
4.	$(1.96 < time1 \cdot max\{-bestbidq2, quant1 - avgret10\} \cdot max\{-bestbidq2, quant1 - avgret10\})$ and $(offcount1 \geq bestbid2 + min\{bestbidq, (bestbid2 + bestbidq2 \cdot 5.32)\} \cdot \frac{lagr1}{quant2})$	4.056	-1.231	-3.490	48.97	-0.64	>0.5000	-0.53	>0.5000	0.3385
5.	$(bestoffq \cdot quant1 \geq min\{depthbid1, 5.416\})$ or $(bestoffq2 \leq min\{max\{bestoffq, 7.59\}, \frac{(lagr1+minret10) \cdot quant2}{min\{max\{3.15, liqoff\}, offcount2 \cdot quant2\}}\})$	4.026	-5.129	-7.415	45.68	-2.38	>0.5000	-2.22	>0.5000	0.7345
6.	$((avgpr20 > avgpr10)$ and $(max\{bestoff, bestoffq2\} < bestoff2))$ or $((quant1 > 1)$ and $(price \leq lagpr2))$	3.943	3.439	1.384	51.03	0.48	0.3156	1.49	0.0681	0.0535
7.	$(((1.843 < time1)$ or $(bestoffq2 < quant))$ and $(quant > 1))$ or $(depthbid1 < 4.85)$	3.929	-3.185	-5.443	47.33	-1.47	>0.5000	-1.37	>0.5000	0.5415
8.	$(5.97 \cdot bestoffq2 \cdot bestbidq1 < depthoff \cdot bestbidq1 - 80.14)$ or $(avgpr10 > avgret10 \cdot price)$	3.865	8.542	6.428	53.50	2.15	0.0158	3.63	0.0001	0.0035
9.	$(quant1 > maxret10 + ret)$ or $((quant1 > 1.23)$ and $(lagpr1 < time1))$	3.607	0.648	-1.705	47.74	-1.16	>0.5000	0.27	0.3936	0.1585
10.	$((1.15 < quant1)$ or $(avgpr10 - liqbid2 \geq time)$ and $(time1 \geq 4.64 - bestoff)$	3.566	-0.269	-2.485	49.11	-0.64	>0.5000	-0.11	>0.5000	0.2245
11.	$(quant1 > 1.35)$ and $(3.04 \leq max\{time, time1\})$	3.549	0.597	-1.861	48.15	-0.96	>0.5000	0.25	0.4013	0.1595
12.	$(1 < quant2)$ and $((time \geq 4.24)$ or $(time1 > price))$	3.435	0.812	-1.690	47.87	-1.09	>0.5000	0.34	0.3669	0.1435
13.	$(avgre20 \geq ret)$ or $(avgret20 \geq avgret10)$	3.417	5.550	3.591	51.71	1.31	0.0951	2.57	0.0051	0.0125
14.	$bestbid1 < min\{\frac{time1}{1.74}, quant\}$	3.379	-0.159	-2.299	47.87	-1.31	>0.5000	-0.06	>0.5000	0.2155
15.	$(quant1 > bestbidq)$ or $((2.98 - bestbidq1 - bestoffq \geq min\{quant1, 0.34\} + minret10) \cdot \{8.345 - \frac{minpr10}{lagr1} - bestbidq\})$	3.351	-0.375	-2.679	49.52	-0.29	>0.5000	-0.16	>0.5000	0.2335
16.	$(6.85 < depthoff1 - bidcount)$ or $(quant2 - 0.82 \geq avgpr10)$	3.300	1.407	0.861	48.70	-0.31	>0.5000	1.05	0.1469	0.1025
17.	$(9.6 < max\{depthoff1 \cdot ret, bidcount1\})$ and $(avgpr10 > price)$	3.210	4.955	2.624	53.50	1.93	0.0268	2.04	0.0207	0.0155
18.	$(max\{quant1, bestbidq\} \geq bidcount)$ or $(max\{quant1 \cdot bestbid2, maxret5, \frac{2.23 \cdot minpr10 - lagr1 \cdot 6.09, bestbid2}{bestoff}\} > bidcount)$	3.124	0.251	-1.056	48.42	-0.65	>0.5000	0.11	0.4562	0.1785
19.	$(max\{bestoffq, 7.8, depthoff\} \geq max\{depthbid2, 8.28\})$ or $(1.27 \geq time)$	3.126	-0.692	-1.615	47.74	-1.01	>0.5000	-0.32	>0.5000	0.2735
20.	$(bestbid2 > price + liqoff1)$ or $(3.66 > \frac{minpr10 - bidcount2}{min\{price, liqbid \cdot 1.9\}} - bestoffq)$	3.016	8.351	6.383	52.54	1.34	0.0901	3.84	<0.0001	0.0035
21.	Average	4.668	0.810	-1.586	48.42	-0.78	>0.5000	0.34	0.3669	0.1435

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.005$

	Technical rules	In-sam. Ret., %	Out-of-sam. Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	(bestoffq2 ≥ lagret2) and (bestoffq1 ≥ ret) and (bestoffq − ret) ≥ ret)	4.198	4.774	4.418	59.09	2.20	0.0139	1.99	0.0233	0.0345
2.	(bestoffq > bestbid2) or (bestbid2 ≥ min{max{bidcount, quant2}, | max{bidcount, quant2 − 4.89}})	3.971	3.876	3.530	58.18	1.98	0.0239	1.63	0.0516	0.0535
3.	(offcount1 − time < bestbidq2) or (bestbidq2 < bestoffq)	3.639	1.675	1.432	54.55	1.40	0.0808	0.79	0.2148	0.1415
4.	((||time − bestoffq1| − avgret20| − 7.88| > bestbidq2) and (bestoffq ≥ maxret20) and ((time ≤ maxret20) or (depthoff > liqoff))	3.596	2.606	2.279	59.09	2.20	0.0139	1.12	0.1314	0.0945
5.	((liqoff1 < 0.24) and ((min{avgret20, quant2} = bestbid2) or (minret5 > bestoff))) or (bestbidq ≥ max{quant, bestbidq, bestbid})	3.546	3.738	3.379	56.36	1.54	0.0618	1.55	0.0606	0.0585
6.	((quant1 < min{8.14, bestoffq}) or(2.9 < |bestbid − 1.7|))and(3.08 ≥ bestbidq)	3.546	1.072	0.722	52.73	0.79	0.2148	0.47	0.3192	0.1775
7.	(quant1 < bestoffq) and ((avgret10 + bestbidq) · maxpr10 ≤ 8.27)	3.546	1.221	0.858	52.73	0.78	0.2177	0.53	0.2981	0.1705
8.	(bestbidq2 · minret20 < 5.04) and (quant2 < bestbidq)	3.545	−0.362	−0.703	49.09	0.00	0.5000	−0.15	>0.5000	0.3155
9.	(max{quant2, price} < min{bestoffq, 3.38} − avgret5) or (max{bestbid1, quant2} < min{bestoffq, 8.7, time1})	3.537	0.519	0.144	51.82	0.58	0.2810	0.23	0.4090	0.2335
10.	(bestoffq > bestbidq2) and (4.63 · bestoffq + quant > 8.7)	3.531	1.754	1.395	57.27	1.55	0.0606	0.75	0.2266	0.1375
11.	(5.41 ≤ bestbidq1 · bestoffq) and (bestbidq1 ≤ 3.08 + maxpr5)	3.518	1.318	1.062	50.00	0.23	0.4090	0.71	0.2389	0.1605
12.	(bestbidq1 > bestbid · 6.96) or (bestoffq ≥ max{ $\frac{bestbid2}{time}$, maxpr10} · avgpr20)	3.517	1.805	1.432	56.36	1.56	0.0594	0.77	0.2206	0.1355
13.	(−5.94 · bestbid1 > −0.069 − bestbidq1) or (avgret10 < avgret20) or (3 ≤ bestoffq)	3.301	−0.139	−0.464	50.91	0.41	0.3409	−0.07	>0.5000	0.2945
14.	((4.09 < bestbidq1) and (min{minret5, liqoff} > time2)) or (bestoffq ≥ max{bestoff, bestbidq, quant2})	3.225	1.640	1.289	54.55	1.15	0.1251	0.69	0.2451	0.1425
15.	(9.87 < bestbidq1) or (bestoffq ≥ $\frac{bestoff1+bestbidq1}{min\{bestbidq1,bestoff2+\frac{price}{time2}\}}$)	3.212	1.782	1.403	56.36	1.54	0.0618	0.75	0.2266	0.1365
16.	(5.9 ≥ max{bestoffq1, $\frac{liqbid2}{1.9 \cdot quant1}$}) and ((bestoff1 < bestoffq) or (quant > 2 · price))	3.212	1.839	1.520	56.36	1.39	0.0823	0.80	0.2119	0.1325
17.	(bestoffq ≥ min{bestbidq2, depthbid} and (bestoffq > 1))	3.209	1.829	1.476	57.27	1.74	0.0409	0.78	0.2177	0.1335
18.	(min{3.22, quant2} < max{quant2, bestoffq})	3.200	0.727	0.318	51.82	0.38	0.3520	0.30	0.3821	0.2085
19.	quant2 ≥ bestoffq · (ret − 2.41) + 4.94	3.175	1.575	1.183	56.36	1.35	0.0885	0.66	0.2546	0.1475
20.	(bestbidq = bestoffq1) and (liqoff + bestoffq1 > bestoffq2)	3.164	−2.100	−2.257	46.36	−0.84	>0.5000	−1.28	>0.5000	0.5115
21.	**Average**	**3.868**	**1.664**	**1.299**	**54.55**	**1.15**	**0.1251**	**0.70**	**0.2420**	**0.1415**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.01$

Technical rules	In-sam., Ret., %	Out-of-sam., Ret., %, $\theta = 0$	O-of-s, Ret., $\theta = 10^{-4}$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (offcount $\leq$ 9.98) and (time2 $-$ maxret20 $<$ maxpr10)	1.744	-3.335	-3.406	42.86	-1.38	>0.5000	-7.98	>0.5000	0.6635
2. (bestoffq1 $<$ avgpr5) or (9.7 $\geq$ |bestoff $\cdot$ (7.95 $-$ offcount2) $\cdot$ (6.58 $-$ minpr10)|)	1.779	-0.561	-0.673	42.86	-0.88	>0.5000	-0.24	>0.5000	0.4175
3. (offcount $<$ 9.88) and ((1 $<$ quant) or (quant $<$ avgret10))	1.744	2.983	2.893	54.76	0.57	0.2843	1.76	0.0392	
4. (time1 $\geq$ quant) and (time1 $\geq$ bestbid) and (maxret20 $\leq$ depthoff2)	1.744	-0.243	-0.389	45.24	-0.24	>0.5000	-0.12	>0.5000	0.3895
5. (7.33 $>$ |offcount $-$ max{bestoffq, liqoff2}|) and (time2 $\leq$ 9.46)	1.744	-0.966	-1.078	50.00	0.15	0.4404	-1.03	>0.5000	0.4635
6. (quant1 $>$ 2) or (lagpr1 $>$ bestoff2)	1.744	0.248	0.108	50.00	-0.17	>0.5000	0.12	0.4522	0.3345
7. ($-\frac{\text{depthoff1}}{\max\{4.45,\text{maxret20,offcount}\}} \leq$ 8.23 $-$ offcount) and (4.7 $>$ time2)	1.744	-4.098	-4.181	40.48	-1.74	>0.5000	-9.82	>0.5000	0.7245
8. (($\frac{\max\{\text{depthoff1,liqoff2}\}}{7.84}$ $>$ bestbidq1) and (avgpr10 $<$ time1)) or (avgpr10 $=$ time1)	1.744	-1.856	-1.980	45.24	-0.44	>0.5000	-0.79	>0.5000	0.5465
9. ((0.47 $<$ liqbid2 $+$ |(bidcount1 $-$ bidcount2) $\cdot$ (1.7 $-$ quant2)|) and (6.755 $\cdot$ avgpr20 $\geq$ 1.46)) or (bestbid1 $=$ lagret2)	1.744	1.819	1.683	54.76	0.92	0.1788	0.80	0.2119	0.1885
10. (bestoffq1 $\leq$ minpr20) or (bestbidq1 $\leq -\frac{5.96}{6.85-\text{offcount}}$)	1.744	0.477	0.377	47.62	-0.20	>0.5000	0.20	0.4207	0.3135
11. ($\frac{\text{avgpr10}}{\text{bestbidq}} \leq$ bestoffq) and (depthoff1 $\geq$ 8.17 $\cdot$ ret $-$ avgret5)	1.744	2.553	2.430	61.90	1.61	0.0537	1.38	0.0838	0.1295
12. (time1 $\geq$ price) and (maxpr5 $\geq$ bestoff2)	1.744	-1.767	-1.900	38.10	-1.23	>0.5000	-0.75	>0.5000	0.5375
13. offcount2 $\geq$ offcount	1.744	1.431	1.282	52.38	0.32	0.3745	0.60	0.2743	0.2235
14. (offcount2 $\geq$ maxret5) and (lagpr2 $<$ time1)	1.744	-0.057	-0.190	45.24	-0.22	>0.5000	-0.04	>0.5000	0.3645
15. (6.36 $>$ minpr5) and (depthoff $<$ depthoff2)	1.744	1.827	1.664	50.00	0.00	0.5000	0.77	0.2206	0.1875
16. (8.37 $\geq$ max{offcount1,3.33}) and (3 $<$ depthbid)	1.744	-3.815	0.96114	38.10	-1.74	>0.5000	-3.62	>0.5000	0.7015
17. (bestbid1 $\leq$ time1) and (time1 $<$ depthoff) and (lagpr1 $<$ time1)	1.744	-1.430	-1.568	45.24	-0.36	>0.5000	-0.67	>0.5000	0.5115
18. (quant2 $>$ 2.39) or (avgret5 $>$ max{time, minret5})	1.744	0.381	0.281	50.00	-0.22	>0.5000	0.16	0.4364	0.3245
19. (4 $<$ depthoff) and (8.38 $>$ liqbid1 $+$ min{offcount1, 8.66})	1.744	-2.496	-2.593	45.24	-0.88	>0.5000	-2.46	>0.5000	0.6105
20. (0.71 $\cdot$ time1 $>$ time) or (maxret5 $>$ max{minret20, bestbidq1})	1.744	-2.625	-2.793	35.71	-1.90	>0.5000	-1.14	>0.5000	0.6195
21. Average	**1.744**	**-0.447**	**-0.586**	**50.00**	**-0.06**	**>0.5000**	**-0.19**	**>0.5000**	**0.4115**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 9 of best 19 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0$

Technical rules	In-sam., Ret., $\theta=10^{-4}$	Out-of-s., Ret., $\theta=10^{-4}$	Out-of-s., Ret., $\theta=0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $0.032718 < \text{lagpr1} \cdot (\text{minret20} + 14.407 + \text{maxpr5} - \frac{0.4314}{\text{minpr5}}) \cdot (\text{avgpr20} - \text{minpr10})$	1.761	3.930	6.291	50.48	0.97	0.1660	3.54	0.0002	0.2425
2. $0.02524 < \text{lagpr1} \cdot (\text{lagret1} + 14.437 + \text{minpr10} - \text{avgpr20}) \cdot (\text{avgpr20} - \text{minpr10})$	1.642	2.760	5.333	49.69	-0.48	>0.5000	2.66	0.0039	0.2725
3. $\text{minret20} < 0.9992$	1.511	3.134	4.066	50.52	0.97	0.1660	2.20	0.0139	0.2605
4. $\text{maxret10}^2 < \frac{\text{lagret2} - \text{avgpr10}}{(8.7657 - 6.391 \cdot \text{minret5} \cdot \text{avgpr10})}$	1.247	2.825	3.292	51.15	1.91	0.0281	1.67	0.0475	0.2695
5. $3.0792 \le \frac{2.188}{\text{minret10}} - \frac{\text{minret5}}{8.88/3 + \text{maxret20}}$	0.992	-0.430	0.216	50.17	0.50	0.3085	0.19	0.4247	0.4015
6. $\text{price} - \text{maxret20} < 0.62988$	0.971	3.724	4.321	51.35	2.32	0.0102	2.28	0.0113	0.2445
7. $\text{price} < 1.6410$	0.935	1.918	2.033	50.23	1.55	0.0606	4.54	<0.0001	0.3275
8. $\text{price} < 1.6315$	0.629	7.127	7.807	51.17	2.15	0.0158	4.37	<0.0001	0.3405
9. $\text{price} < 1.6346$	0.615	5.822	6.268	50.69	1.53	0.0630	4.29	<0.0001	0.2065
10. sell	0.095	-0.062	-0.055	49.96	0.00	0.5000	0.00	0.5000	0.3865
11. Average	**1.500**	**2.850**	**3.531**	**50.87**	**1.50**	**0.0668**	**1.89**	**0.0294**	**0.2695**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

$k = 0.0005$

Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. minpr20 $< \frac{4.289}{maxpr10} -$ maxret20	1.244	4.632	4.873	51.48	1.99	0.0233	2.63	0.0043	0.0095
2. minret10 + minret20 > maxpr20 + 0.3638	0.982	0.159	0.393	49.39	0.06	0.4761	0.22	0.4129	0.2805
3. maxpr5 $\leq$ avgpr20 · maxret20	0.559	-0.006	2.088	49.26	-0.33	>0.5000	0.96	0.1685	0.4055
4. maxret20 > ret · avgret5	0.514	1.764	3.661	50.61	1.72	0.0427	2.71	0.0034	0.0935
5. maxret5 · avgret10 $\leq$ avgret5	0.493	-0.547	0.125	50.74	-0.38	>0.5000	0.20	0.4207	0.4925
6. ret < maxret20	0.180	3.155	6.133	50.61	1.67	0.0475	3.66	0.0001	0.0315
7. maxret5 = avgret5	0.167	-0.417	-0.277	50.74	-1.22	>0.5000	-0.61	>0.5000	0.4645
8. avgpr10 = price	0.166	-0.014	0.020	51.14	1.42	0.0778	0.36	0.3594	0.4065
9. (minret20 > 1.04) or (lagpr2 = avgpr10)	0.155	-0.118	-0.015	51.08	0.43	0.3336	0.09	0.4641	0.4215
10. avgret20 $\leq$ minret10	0.154	0.183	0.241	51.01	0.04	0.4840	1.31	0.0951	0.2755
11. Average	**0.638**	**0.039**	**2.818**	**50.87**	**0.56**	**0.2877**	**1.23**	**0.1093**	**0.3055**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0.001$

Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (ret ≤ minret20) and (lagret1 < maxret10)	4.319	3.676	5.012	53.30	2.05	0.0201	3.17	0.0008	0.1435
2. (price = lagpr2) or (ret = minret20)	3.966	5.304	7.216	54.26	2.45	0.0071	3.84	0.0001	0.0965
3. (avgpr10 = minpr10) or (ret < minret20)	3.545	5.420	7.349	54.67	2.77	0.0028	3.94	<0.0001	0.0965
4. (price ≤ minpr20) or (lagpr1 = minpr5)	3.175	3.607	5.678	52.61	1.38	0.0838	2.43	0.0075	0.1445
5. (minret20+avgpr10−minpr10 > lagret1) and (price < max{minpr5, avgpr10})	3.175	5.770	7.871	53.02	1.57	0.0582	3.30	0.0005	0.0915
6. price ≤ maxret10 · minpr10	2.784	4.438	6.804	53.02	1.67	0.0475	2.89	0.0019	0.1185
7. (ret ≤ minret10) or (avgret10 ≤ minret10)	2.723	4.164	6.338	53.16	1.69	0.0455	3.10	0.0010	0.1235
8. (max{$\frac{price}{avgpr10}$, avgret5} = ret) or (maxpr5 < avgpr10) or (minret10 = ret)	2.720	3.395	5.785	52.75	1.41	0.0793	2.60	0.0047	0.1535
9. (ret < maxret20) and (minpr5 ≤ minpr20)	2.273	6.802	8.836	52.34	1.21	0.1131	3.73	0.0001	0.0735
10. (ret < avgret5) and (ret < lagret1)	2.168	4.831	7.534	52.06	1.07	0.1423	3.21	0.0007	0.1075
11. Average	**2.614**	**3.594**	**5.828**	**52.61**	**1.34**	**0.0901**	**2.68**	**0.0037**	**0.1445**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

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$k = 0.005$

Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. (lagpr1 > avgpr20 · minret10) and (minpr20 > price · minret10)	5.847	4.427	5.808	61.32	2.45	0.0071	2.69	0.0036	0.0745
2. (minret20 = ret) or (lagret1 − minret5 + minret20 = minret10)	5.562	3.346	3.726	58.49	1.78	0.0375	1.61	0.0537	0.0985
3. (ret = minret20) or (avgret10 < avgret20)	5.287	2.843	3.179	58.49	1.80	0.0359	1.37	0.0853	0.1075
4. (maxpr5 = lagpr1) or (minret10 = max($\frac{minpr20}{lagpr2}$, minret5 · minret5))	5.133	0.608	0.869	54.72	1.02	0.1539	0.38	0.3520	0.1545
5. $\frac{6.55}{maxpr20} \geq 0.719 +$ price $+$ minpr10	5.129	2.436	2.477	52.83	1.39	0.0823	3.70	0.0001	0.1145
6. ((minpr5 = lagpr2) and (minpr20 = lagpr2)) or (minret20 = minret5)	4.361	2.289	2.617	53.77	0.79	0.2148	1.14	0.1271	0.1055
7. ret = minret20	4.324	7.518	7.912	67.92	4.41	<0.0001	4.04	<0.0001	0.0355
8. (avgret10 < avgret20) or (avgret20 < avgret5)	3.943	-0.763	-0.624	50.00	0.00	0.5000	-0.56	>0.5000	0.2285
9. (avgret5 ≥ lagret2) and (avgret5 ≥ ret)	3.785	4.148	4.475	58.49	1.96	0.0250	2.08	0.0188	0.0805
10. (1 ≤ avgret10) and (avgret20 ≤ lagret1) and (minpr5 ≤ lagret2 · lagpr1)	3.664	-3.887	-3.662	45.28	-1.10	>0.5000	-1.93	>0.5000	0.3145
11. Average	6.252	3.743	4.111	60.38	2.19	0.0143	1.77	0.0384	0.0895

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

$k = 0.01$

	Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	$\frac{minret20 - avgret5}{minret5 \cdot avgret5 - avgret20 \div avgpr10 \cdot 0.3888} \geq minpr5$	1.667	-0.292	-0.239	48.72	-0.11	>0.5000	-0.20	>0.5000	0.3495
2.	$3.2678 \geq avgpr20 + minpr5$	1.667	1.048	1.082	56.41	1.88	0.0301	1.19	0.1170	0.1515
3.	$(avgpr10 < avgpr5)$ or $(lagpr1 < avgpr5)$	1.667	-0.780	-0.734	51.28	0.56	0.2877	-1.12	>0.5000	0.4225
4.	$avgpr5 > avgpr10$	1.045	-1.313	-1.148	38.46	-1.47	>0.5000	-0.51	>0.5000	0.4775
5.	$(lagret2 \geq avgret20)$ and $(avgret5 \leq lagret1)$	1.045	1.107	1.222	58.97	1.24	0.1075	0.61	0.2709	0.1495
6.	$(avgpr5 > lagret1 - minpr20)$ or $(avgret10 < lagret2)$	1.038	-0.495	-0.449	46.15	-0.65	>0.5000	-0.39	>0.5000	0.3815
7.	$avgpr20 \leq minpr5$	0.993	-2.961	-2.851	33.33	-2.62	>0.5000	-1.61	>0.5000	0.6505
8.	$(ret > avgret10)$ and $(minret10 > minret20)$	0.993	-0.577	-0.518	48.72	-0.42	>0.5000	-0.29	>0.5000	0.3955
9.	$(ret > minret5)$ and $(minpr5 > minpr20)$	0.993	-0.518	-3.352	30.77	-2.99	>0.5000	-1.78	>0.5000	0.3835
10.	$(lagpr1 > lagpr2)$ and $(ret > avgret10)$	0.993	-1.506	-1.460	46.15	-1.03	>0.5000	-5.29	>0.5000	0.4975
11.	**Average**	**1.045**	**-1.495**	**-1.383**	**43.59**	**-0.80**	**>0.5000**	**-0.69**	**>0.5000**	**0.4965**

Trading rules based on the pure price information only. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

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GA based no-transaction region

Technical rules	In-sample $\theta = 0.0001$	Out-of-s $\theta = 0.0001$
1a. $\frac{1.6324}{minret5} > \max\{\text{price}, avgpr10\}$ 1b. true	1.836	3.542
2a. $2.6361 \geq minret10 + maxpr20$ 2b. true	1.401	3.544
3a. $3.2724 > maxpr10 + minpr10$ 3b. true	1.198	2.939
4a. false 4b. $5.4633 \leq \frac{maxret10 \cdot maxret20}{1.18225 \cdot avgret20 - minret5}$	1.148	2.565
5a. false 5b. $1.639 < \text{price}$	0.892	1.562
6a. false 6b. $|\text{price} - maxpr10| \leq 0.0036$	0.753	2.802
7a. $(1.00524 \geq \text{ret})$ and $(1.00524 < maxret20)$ 7b. true	0.689	1.782
8a. $(minpr20 + 7.8928 - avgret5 + minret20 \leq \frac{9.77 \cdot avgret5}{avgret20 \cdot avgpr10 \cdot (minpr20 - avgret20)})$ 8b. true	0.664	1.332
9a. $maxpr5 \geq minret20 \cdot 1.648865$ 9b. true	0.652	2.041
10a. false 10b. $\frac{9.93103}{minpr20} + avgret5 < 7.101135$	0.401	0.559

Trading rules based on the pure price information. Buy if a) rule is true, Sell if a) is false and b) is true, No Trade if both a) and b) are false. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday.

$k = 0$

Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $((7.16 < |8.34 - \text{offcount1}|)$ and $(\text{depthbid1} - \text{bestbidq} < \text{bestbidq1}))$ or $(1 \geq \text{depthbid1})$	0.385	-0.919	-0.767	49.97	-0.53	>0.5000	-3.04	>0.5000	0.3265
2. $(\min\{\frac{\min\{|\text{time1}-7.677|,\text{time2}\}\cdot\text{bidcount}}{\text{avgret20}}, \frac{2.143}{\text{depthbid2}\cdot\text{depthbid2}}\} \geq \frac{\min\{\text{price},\text{minpr20-lagpr1}\}}{\text{maxpr10}})$ or $(8.4 \leq \text{liqoff1})$	0.361	-0.109	-0.075	49.97	-1.41	>0.5000	-0.29	>0.5000	0.2705
3. $(\text{depthbid2} - \text{bestoff} \leq 7.3962)$ or $(\frac{\text{time2}-\text{minpr5}}{\text{depthbid1}} > \text{depthbid1})$	0.354	0.405	1.110	50.14	0.53	0.2981	1.37	0.0853	0.2405
4. $(\text{depthbid1} \leq \min\{\text{maxpr10}, \text{bestbidq}\} + \text{minpr20})$ or $(\text{maxret5} = \text{depthbid})$	0.294	-0.644	-0.551	50.03	0.30	0.3821	-2.87	>0.5000	0.3075
5. $(8.19 \cdot \text{avgpr20} \geq \text{depthoff1})$ and $(\text{depthbid1} < 1.23)$	0.287	-0.819	-0.746	50.01	0.00	0.5000	-5.23	>0.5000	0.3225
6. $(6.007 > \max\{\min\{\text{bestoffq} \cdot \text{bidcount2}, 8.7\}, \text{bestoffq1}\})$ and $(\text{maxret10} > \text{depthbid1})$	0.273	-0.900	-0.837	49.95	-1.34	>0.5000	-6.92	>0.5000	0.3255
7. $(\max\{\text{depthbid1}, \frac{\text{avgret5}}{\text{time2}}\} \cdot \text{maxret20} < 1.795)$	0.272	-0.840	-0.454	49.99	-0.38	>0.5000	-4.95	>0.5000	0.3255
8. $(1.22 \cdot \text{bestbid} > \text{depthbid1})$ and $(\text{depthbid} \geq 0.8)$	0.255	-0.840	-0.754	49.99	-0.38	>0.5000	-4.95	>0.5000	0.3255
9. $(\text{bidcount2} \leq \text{lagpr2})$ and $(2.28 > \text{depthoff})$	0.149	-1.832	-1.786	49.99	-0.58	>0.5000	-17.43	>0.5000	0.4085
10. $(\text{liqoff2} \geq 6.036)$ and $(\text{depthoff2} \cdot \text{lagpr2} \cdot \text{bestoff2} < \text{bidcount2} \cdot |\text{quant} - \text{bidcount}| \cdot 17.91)$	0.143	-0.062	-0.055	50.01	0.00	0.5000	0.00	0.5000	0.2685
11. Average	**0.255**	**-0.840**	**-0.754**	**49.99**	**-0.38**	**>0.5000**	**-4.95**	**>0.5000**	**0.3255**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.0005$

	Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	$((\text{minpr5} < \text{bestoff2})$ or $(0.4 \geq \min\{\text{bestoffiq}, \text{offcount2} + \text{liqoff1}\} + \text{liqoff1})$ or $(13 < \text{depthoff})$ $\frac{1}{4.16 - \min\{\text{depthoff1}, \frac{\text{dsthbid1} - 0.9}{12.5}\}} > 1))$ and $(13 < \text{depthoff})$	1.522	-1.044	-0.229	48.89	-0.17	>0.5000	-0.25	>0.5000	0.4625
2.	(depthbid1 < |depthoff + bestbidq2 − 2.192|) or (depthbid1 < 2.19)	1.375	-4.988	-3.719	48.62	-0.81	>0.5000	-1.64	>0.5000	0.8285
3.	(9.76 < offcount) or (bestoffiq2 · bidcount1 < 2.9 · price)	1.146	-2.666	-2.054	49.50	0.68	0.2483	-2.08	>0.5000	0.6415
4.	(quant1 > offcount1) or (offcount > 9)	1.033	0.256	0.839	49.56	0.72	0.2358	0.75	0.2266	0.2905
5.	(2 < bestoffiq2) and (bestoff2 = maxpr20)	1.002	-0.149	0.565	51.18	0.44	0.3300	0.62	0.2676	0.3465
6.	(depthbid1 < max{7.48 + liqbid1, avgpr20}) or (9.74 − avgret5 ≥ maxpr20 · 5.3)	0.994	0.048	0.055	48.89	0.0	0.5000	0.0	0.5000	0.3225
7.	(2.13 < max{liqbid1, minret10} · max{bestoffiq2, 1.26}) and (bestoff2 = bestbid)	0.957	-0.951	-0.454	50.50	-0.15	>0.5000	0.49	0.3121	0.4475
8.	(bestoffiq · maxret5 · bestoff2 > 9.3) or (depthbid1 · maxret5 < min{9.3, $\frac{\text{liqpr1}}{\text{liqpr2}}$})	0.897	-3.064	-0.417	50.03	-0.81	>0.5000	-0.73	>0.5000	0.6795
9.	9.44 · ret ≤ offcount	0.852	-0.761	-0.263	49.63	0.76	0.2236	-0.29	>0.5000	0.4115
10.	depthoff > 2.35 · max{bestbidq, 8.27}	0.827	-0.898	-0.292	48.89	-0.21	>0.5000	-0.25	>0.5000	0.4395
11.	**Average**	**2.342**	**0.152**	**0.842**	**49.02**	**-0.04**	**>0.5000**	**0.69**	**0.2451**	**0.2995**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

WARWICK
BUSINESS SCHOOL

$k = 0.001$

Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1. $((\text{maxret5} \le \text{bestbidq1})$ and $(\text{offcount1} > \max\{9, \text{bestbidq1}\}))$ and $(\text{lagpr1} \le \text{bestoff})$ or $(\text{quant2} > \text{bestoffq})$	3.130	-1.111	1.391	51.71	1.08	0.1401	0.59	0.2776	0.4155
2. $((\text{bestoffq} \cdot \text{bestoffq2} \cdot (\text{bestoffq} + 0.95) \le \text{quant})$ and $(3.22 - \text{quant1} < \text{depthbid}))$ or $(\min\{5.1, \text{bidcount}\} \le \text{bestoffq})$	2.583	-1.634	0.006	50.21	-0.25	>0.5000	0.02	0.4920	0.4595
3. $(\text{price} \le \text{avgpr10})$ and $(\text{quant1} \ge \min\{\text{bestoff}, \max\{\min\text{pr10}, \text{avgpr10} + \text{depthoff} - 4.47\}, \text{bestoffq2}\})$	2.479	2.964	4.855	50.48	0.09	0.4641	2.19	0.0143	0.0835
4. $((\text{offcount} > 7)$ and $(\text{quant} > \min\{\frac{\min\{\text{lagbid}, \text{bestbida}\}}{\text{lagoff1}}, \text{maxret10}\}))$ and $(\text{time} + \text{offcount2} \ge 12.96))$ or $(\text{bestbidq} > 8.45)$	2.320	-1.001	-0.706	48.15	-0.76	>0.5000	-0.38	>0.5000	0.4035
5. $(\text{time1} - \text{quant1} \ge \frac{\text{bestoff2}}{\text{bid1}})$ and $(\text{quant2} > 1)$ and $(\text{bidcount} + \text{quant1} \ge \frac{1.28}{\text{lagpr1}})$	2.241	-2.542	-0.647	49.25	-0.64	>0.5000	-0.29	>0.5000	0.5605
6. $(\text{depthbid} < \text{depthoff1})$ or $((\text{bestoffq} > 5)$ and $(\text{bidcount2} > \text{ret}))$	2.052	-1.613	-0.708	49.38	-0.16	>0.5000	-0.31	>0.5000	0.4575
7. $(5 < \text{bestoffq})$ or $(\text{quant} > 3)$	1.997	-0.997	0.191	51.71	0.86	0.1949	0.13	0.4483	0.4035
8. $(\text{maxpr20} - \max\{\text{minret5}, \text{time}\} > 0.34)$ and $(\text{minret5} < \text{quant2})$	1.155	-2.012	-1.078	50.21	-0.32	>0.5000	-0.65	>0.5000	0.5025
9. $(2.5 \cdot \text{offcount1} > \text{bidcount2})$ and $(19 > \text{offcount2})$	1.601	-2.193	-1.567	50.34	0.27	0.3936	-0.62	>0.5000	0.5255
10. $\text{bestoffq} > 5$	1.585	-1.274	-0.660	49.93	-0.83	>0.5000	-0.46	>0.5000	0.5725
11. Average	**4.328**	**-1.913**	**-0.058**	**49.11**	**-0.71**	**>0.5000**	**-0.02**	**>0.5000**	**0.4935**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

WARWICK BUSINESS SCHOOL

$k = 0.005$

	Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	(bestbidq2 $\leq$ 5) and (max{|(bestbidq1 − 6.7) · (liqbid + 3.6)|, minpr5} $\geq$ min{liqbid1, 3.2}) and (bestbidq1 > 1) and (bestoffiq > min{quant2, 5.16})	4.137	1.026	1.350	50.00	0.22	0.4129	0.65	0.2578	0.1895
2.	(minpr20 $\geq \frac{3.81}{avgret10 - minpr10}$) and (depthhid $\leq$ bestoffiq · max{min{depthhid, depthhid1} − max{bidcount, 2.12}, bestoffiq})	3.162	2.570	2.965	55.45	1.36	0.0869	1.26	0.1038	0.0895
3.	(bestoffiq > lagret2) and ((8.6 = liqbid)or(bestbidq1 > lagret2·1.99))	3.060	1.141	1.520	52.73	0.80	0.2119	0.68	0.2483	0.1615
4.	(bestoffiq − liqoff > 1.62) and (minpr10 = minpr5)	2.841	1.961	2.308	57.27	1.74	0.0409	0.96	0.1685	0.1315
5.	((min{8.63, bestoffiq1} > price) and (4.72 > bestoffiq1)) or (min{bestoffiq, avgpr20} > price)	2.835	3.982	4.266	59.09	2.16	0.0154	1.83	0.0336	0.0505
6.	((bestbidq · bestoffiq2 − bestbidq − lagpr2) 6.97 $\leq$ bestoff1 · bestoffiq · bestoff2) and (bestoffiq2 $\leq$ bestoff2 + 3)	2.546	0.175	0.924	54.55	1.25	0.1056	0.39	0.3483	0.2675
7.	(bestbidq $\leq$ 3) and (price $\leq$ lagpr2)	2.528	5.140	5.519	60.91	2.58	0.0049	2.29	0.0110	0.2335
8.	($\frac{3.23}{depthbidq}$ + bestoffiq2 < 4.05) or (avgret10 $\leq$ avgret20)	2.284	3.367	3.539	55.45	1.74	0.0409	2.19	0.0143	0.0585
9.	(offcount1 · bestoffiq2 $\leq$ depthoff) or (offcount1 $\leq$ time)	2.268	-0.321	-0.101	48.18	-0.46	>0.5000	-0.07	>0.5000	0.3175
10.	avgret20 $\geq$ min{ret, avgret10}	2.196	5.017	5.367	49.93	2.60	0.0047	2.52	0.0059	0.0315
11.	**Average**	**4.362**	**5.368**	**5.672**	**60.00**	**2.35**	**0.0094**	**2.36**	**0.0091**	**0.0275**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

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$k = 0.01$

	Technical rules	In-sam., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 10^{-4}$	Out-of-s., Ret., $\theta = 0$	DC, %	P-T stat.	P-T p-value	A-G stat.	A-G p-value	White's p-value
1.	$(6.157 + \text{minret10} < \text{depthbid1})$ and $(\text{time1} \geq \text{bestoff2})$	1.703	-1.353	-1.514	47.62	0.00	0.5000	-0.55	>0.5000	0.5295
2.	$(\text{offcount2} > 1)$ and $(\text{offcount2} < 11)$	1.703	-1.309	-1.237	42.86	-0.99	>0.5000	-1.11	>0.5000	0.5255
3.	$(\text{ligoff} < 4.415)$ and $(\text{depthoff} < \text{depthoff2})$	1.703	1.664	1.827	50.00	0.0	0.5000	0.77	0.2206	0.2215
4.	$(7.6 \geq \text{maxpr20} + \frac{\text{offcount2}}{1.72})$ and $(7 \leq \text{offcount2})$	1.703	-0.492	-0.472	47.62	-1.86	>0.5000	-3.01	>0.5000	0.4505
5.	$(\text{offcount} > 3)$ and $(\text{time1} > \text{bestoff1})$	1.703	-1.463	-1.331	45.24	-0.29	>0.5000	-0.64	>0.5000	0.5415
6.	$(\text{offcount1} < 9)$ and $(\text{time2} < \text{minret10} \cdot 9.3176)$	1.703	-2.414	-2.316	47.62	-0.28	>0.5000	-5.96	>0.5000	0.6465
7.	$\text{avgpr5} \cdot \text{time} \leq \text{time1}$	1.651	-2.806	-2.670	35.71	-1.97	>0.5000	-1.20	>0.5000	0.6835
8.	$(20.52 \cdot \text{time2} > \text{maxret20} + \text{bestbid1})$ and $(\text{depthbid} \geq \text{depthoff1})$	1.651	-2.079	-1.968	38.10	-1.61	>0.5000	-0.92	>0.5000	0.6105
9.	$(\text{quant2} \leq \text{avgret10})$ or $(\text{time1} \geq 5.31)$	1.092	1.684	1.806	50.00	0.32	0.3745	0.75	0.2266	0.2205
10.	$(\text{lagpr2} < \text{maxpr5})$ and $(6 \leq \text{depthbid1})$	1.087	-1.249	-1.143	42.86	-0.88	>0.5000	-0.76	>0.5000	0.5205
11.	**Average**	**1.703**	**-0.886**	**-0.774**	**47.62**	**-0.13**	**>0.5000**	**-0.38**	**>0.5000**	**0.4905**

Trading rules based on the all order book information. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday. The average rule gives buy signal if more than 4 of best 9 rules give buy signal and sell otherwise.

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GA based no-transaction region

Technical rules	In-sample $\theta = 0.0001$	Out-of-s $\theta = 0.0001$
1a. $(\max\{6.166, 2.3 \cdot (\text{liqbid1} \cdot 14.564 + \text{avgpr5})\max\text{pr10}, 18.41 - \text{bidcount}\} \leq 8.438)and(\max\text{pr10} \leq \text{liqbid1} \cdot \text{minpr20} \cdot 8 + \text{avgpr5})$ 1b. true	1.988	1.203
2a. $(77.827 \cdot \text{liqoff1} \cdot \text{bestoff2} \cdot \text{liqbid} \geq \text{minpr20}^2 \max\{4.712, \text{time}\} \cdot \max\{\text{avgpr10}, \text{time}\})and(2.64 \geq \text{depthbid1})$ 2b. $\frac{10}{1.5437 - \text{price}} < \text{minret5}$	1.009	0.000
3a. false 3b. $0.99723 \leq \text{minret5}^2$	0.901	2.809
4a. $(\text{avgpr5} - \max\{\text{liqoff1}, \text{minpr20}\} = \text{liqbid} - \text{avgret5})or(3.918 < \text{liqbid2})$ 4b. $(\text{price} \cdot \text{maxret10} \geq \text{bestbid})or(\text{price} \cdot \text{maxret20} \geq \text{bestbid} \cdot \text{maxret10})$	0.803	2.881
5a. false 5b. $(1.63289 \leq \text{minpr20})or(\max\{\min\{\text{depthbid1}, |\text{time2} - \text{maxpr10}|\}, 3.48\} = \text{depthoff} - \text{bestbidq1})$	0.721	0.123
6a. $(\frac{\text{bestoffq1}}{\text{time2}} + \text{avgpr10} \leq 4.1)and(\frac{0.4965}{\text{bestoffq1}} + \text{avgpr10} \geq \text{depthbid1})$ 6b. true	0.538	-0.840
7a. $1.5 > \text{depthbid1}$ 7b. $\text{minpr5} - \text{maxret20} \geq 0.627$	0.466	-0.366
8a. $(\max\{\text{bidcount} - \frac{\text{bestoff2}}{\text{avgret20} \cdot \text{depthbid2}} < 5.1)and(\max\{\text{bidcount} - \frac{\text{lagpr2}}{\text{bidcount}}, \text{depthoff}\} \geq \frac{6.77}{\text{bidcount} - \text{bestoffq} \cdot 0.637}$ 8b. $(1.1 \leq \text{offcount})or(\text{liqbid} > 1.766)$	0.453	-0.757
9a. $(\text{bestbid1} > \min\{\text{bestoffq1}, \text{bestbidq2}\})and(\text{depthbid1} \leq 2.7)$ 9b. true	0.453	-0.181
10a. $(5.0 \geq \text{depthbid2})or(\text{bestbid1} > 34 + (\text{lagpr1} - \text{time2}) \cdot 0.1)$ 10b. $(\max\{\text{depthbid}, \text{depthoff} - 6.5\} \geq 2.7)or(\text{bidcount1} \leq \text{maxret20})$	0.402	1.786

Trading rules based on the all order book information. Buy if a) rule is true, Sell if a) is false and b) is true, No Trade if both a) and b) are false. The fitness function is the cumulative return for 3 days trading under proportional transaction costs, $\theta = 0.0001$. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday.

Average Rules: Pure Price Info

Fitness function: directional changes

k	In-sample, Dir. change., %	Out-of-sample, Dir.Ch., %	Daily return, %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	55.10	54.11	2.150	-6.123	5.98	<0.0001	0.93	0.1762	0.0055
0.0005	58.50	51.95	6.559	3.062	1.28	0.1002	2.49	0.0064	0.1255
0.001	58.66	54.12	8.051	5.763	2.19	0.0143	3.42	0.0003	0.0295
0.005	76.00	67.92	8.340	7.885	3.97	<0.0001	3.54	0.0002	0.0125
0.01	83.33	64.10	2.310	2.208	2.27	0.0116	1.11	0.1335	0.1105

Fitness function: cumulative returns, no-transaction costs

k	In-sample, Daily ret., %, $\theta = 0$	Out-of-sample, Daily ret., %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	5.654	8.327	-10.267	51.00	1.44	0.0749	3.51	0.0002	0.0025
0.0005	3.460	6.676	1.833	51.75	1.31	0.0951	2.84	0.0023	0.0065
0.001	3.555	4.150	2.190	52.75	1.42	0.0778	1.88	0.0301	0.0165
0.005	1.813	8.690	8.198	69.81	4.48	<0.0001	3.71	0.0001	0.0015
0.01	1.645	1.447	1.359	51.28	0.20	0.4207	0.65	0.2578	0.0745

Fitness function: cumulative returns, $\theta = 0.0001$

k	In-sample, Daily ret., %, $\theta = 10^{-4}$	Out-of-sample, Daily ret., %, $\theta = 10^{-4}$	Daily return, %, $\theta = 0$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	1.500	2.850	3.531	50.87	1.50	0.0668	1.89	0.0294	0.2695
0.0005	0.638	0.039	2.818	50.87	0.56	0.2877	1.23	0.1093	0.3055
0.001	2.614	3.594	5.828	52.61	1.34	0.0901	2.68	0.0037	0.1445
0.005	6.252	3.743	4.111	60.38	2.19	0.0143	1.77	0.0384	0.0895
0.01	1.045	-1.495	-1.383	43.59	-0.80	>0.5000	-0.69	>0.5000	0.4965

Average of best 20 trading rules for different fitness functions based on the pure price information. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday.

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Average Rules: All Order Book Info

Fitness function: directional changes

k	In-sample, Dir. change., %	Out-of-sample, Dir.Ch., %	Daily return, %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	58.78	57.30	5.821	-3.202	10.72	<0.0001	2.40	0.0082	<0.001
0.0005	64.51	51.31	3.791	0.918	1.88	0.0301	1.91	0.0281	0.0655
0.001	59.72	46.36	0.222	-2.161	-1.83	>0.5000	0.09	0.4641	0.6765
0.005	85.19	47.27	-0.968	-1.337	-0.38	>0.5000	-0.41	>0.5000	0.5885
0.01	100.00	47.62	-0.985	-1.024	-0.77	>0.5000	-2.27	>0.5000	0.5725

Fitness function: cumulative returns, no-transaction costs

k	In-sample, Daily ret., %, $\theta = 0$	Out-of-sample, Daily ret., %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	9.165	11.830	-8.481	53.37	4.95	<0.0001	4.79	<0.0001	0.0035
0.0005	5.518	1.173	-2.606	49.76	-0.40	>0.5000	0.51	0.3050	0.0795
0.001	4.668	0.810	-1.586	48.42	-0.78	>0.5000	0.34	0.3669	0.1435
0.005	3.868	1.664	1.299	54.55	1.15	0.1251	0.70	0.2420	0.1415
0.01	1.744	-0.447	-0.586	50.00	-0.06	>0.5000	-0.19	>0.5000	0.4115

Fitness function: cumulative returns, $\theta = 0.0001$

k	In-sample, Daily ret., %, $\theta = 10^{-4}$	Out-of-sample, Daily ret., %, $\theta = 10^{-4}$	Daily return, %, $\theta = 0$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	0.255	-0.840	-0.754	49.99	-0.38	>0.5000	-4.95	>0.5000	0.3255
0.0005	2.342	0.152	0.842	49.02	-0.04	>0.5000	0.69	0.2451	0.2995
0.001	4.328	-1.913	-0.058	49.11	-0.71	>0.5000	-0.02	>0.5000	0.4935
0.005	4.362	5.368	5.672	60.00	2.35	0.0094	2.36	0.0091	0.0275
0.01	1.703	-0.886	-0.774	47.62	-0.13	>0.5000	-0.38	>0.5000	0.4905

Average of best 20 trading rules for different fitness functions based on the all order book information. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday.

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Maximum Rules: Pure Price Info

Fitness function: directional changes

k	In-sample, Dir. change., %	Out-of-sample, Dir.Ch., %	Daily return, %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	55.35	52.90	5.786	-9.154	4.21	<0.0001	2.47	0.0068	0.0175
0.0005	56.01	51.28	6.040	3.133	1.07	0.1423	2.57	0.0051	0.2345
0.001	60.07	55.49	9.390	7.317	3.17	0.0008	4.52	<0.0001	0.0065
0.005	84.00	60.38	4.085	3.711	2.21	0.0136	1.76	0.0392	0.0865
0.01	100.00	56.41	1.536	1.414	0.79	0.2148	0.67	0.2514	0.2575

Fitness function: cumulative returns, no-transaction costs

k	In-sample, Daily ret., %, $\theta = 0$	Out-of-sample, Daily ret., %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	6.562	8.689	8.905	51.48	2.15	0.0158	3.67	0.0001	<0.001
0.0005	4.569	6.233	2.477	52.62	1.89	0.0294	2.74	0.0031	0.0065
0.001	3.781	6.049	4.484	51.92	0.98	0.1635	2.61	0.0045	0.0035
0.005	3.292	0.644	0.550	53.77	1.49	0.0681	0.53	0.2981	0.1555
0.01	1.707	-1.062	-1.095	48.72	-0.05	>0.5000	-1.31	>0.5000	0.3635

Fitness function: cumulative returns, $\theta = 0.0001$

k	In-sample, Daily ret., %, $\theta = 10^{-4}$	Out-of-sample, Daily ret., %, $\theta = 10^{-4}$	Daily return, %, $\theta = 0$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	1.671	3.930	6.291	50.48	0.97	0.1660	3.54	0.0002	0.2425
0.0005	1.244	4.632	4.873	51.48	1.99	0.0233	2.63	0.0043	0.0095
0.001	4.319	3.676	5.012	53.30	2.05	0.0201	3.17	0.0008	0.1435
0.005	5.847	4.427	5.808	61.32	2.45	0.0071	2.69	0.0036	0.0745
0.01	1.667	-0.292	-0.239	48.72	-0.11	>0.5000	-0.20	>0.5000	0.3495

Average of best 20 trading rules for different fitness functions based on the pure price information. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday.

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Maximum Rules: All Order Book Info

Fitness function: directional changes

k	In-sample, Dir. change., %	Out-of-sample, Dir.Ch., %	Daily return, %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	58.61	57.30	6.378	-5.628	10.70	<0.0001	2.61	0.0045	<0.001
0.0005	60.24	52.86	1.103	-3.133	2.55	0.0054	0.47	0.3192	0.0055
0.001	63.25	45.82	-1.366	-2.964	-2.13	>0.5000	-0.63	0.4641	0.7505
0.005	85.19	47.27	0.430	0.156	-0.46	>0.5000	0.24	0.4052	0.5885
0.01	100.00	50.00	-0.915	-0.935	0.07	0.4721	-3.68	>0.5000	0.4315

Fitness function: cumulative returns, no-transaction costs

k	In-sample, Daily ret., %, $\theta = 0$	Out-of-sample, Daily ret., %, $\theta = 0$	Daily return, %, $\theta = 10^{-4}$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	8.404	12.256	-0.476	53.76	5.75	<0.0001	5.18	<0.0001	0.0035
0.0005	4.945	-1.098	-5.057	48.89	-1.08	>0.5000	-0.47	>0.5000	0.2825
0.001	4.843	2.008	0.476	50.62	0.67	0.2514	0.87	0.1922	0.0725
0.005	4.198	4.774	4.418	59.09	2.20	0.0139	1.99	0.0233	0.0345
0.01	1.744	-3.335	-3.406	42.86	-1.38	>0.5000	-7.98	>0.5000	0.6635

Fitness function: cumulative returns, $\theta = 0.0001$

k	In-sample, Daily ret., %, $\theta = 10^{-4}$	Out-of-sample, Daily ret., %, $\theta = 10^{-4}$	Daily return, %, $\theta = 0$	Dir. change, %	P-T statistic	P-T p-value	A-G statistic	A-G p-value	White's p-value
0	0.385	-0.919	-0.767	49.97	-0.53	>0.5000	-3.04	>0.5000	0.3265
0.0005	1.522	-1.044	-0.299	48.89	-0.17	>0.5000	-0.25	>0.5000	0.4625
0.001	3.130	-1.111	1.391	51.71	1.08	0.1401	0.59	0.2776	0.4155
0.005	4.137	1.026	1.350	50.00	0.22	0.4129	0.65	0.2578	0.1895
0.01	1.703	-1.353	-1.514	47.62	0.00	0.5000	-0.55	>0.5000	0.5295

Average of best 20 trading rules for different fitness functions based on the all order book information. In-sample period: Monday and Tuesday, out-of-sample: Wednesday – Friday.

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Probabilities based on bootstrap method

Pure Price Information

k	$P\{DC \geq 50\%\}$	Ω_{DC}	$P\{r \geq 0\}$	$P\{r \geq r_{BH}\}$	Ω_{EV}	$P\{r_{TC} \geq 0\}$	$P\{r_{TC} \geq r_{BH}\}$	Ω_{TC}
0	0.943	83.384	0.956	0.974	152.380	0.534	0.607	1.327
0.0005	0.744	4.508	0.939	0.946	36.118	0.571	0.620	1.871
0.001	0.799	7.689	0.915	0.931	43.846	0.798	0.811	9.265
0.005	0.831	14.035	0.893	0.911	26.625	0.869	0.870	15.960
0.01	0.813	6.461	0.753	0.789	6.087	0.731	0.760	5.655

All Order-Book Information

k	$P\{DC \geq 50\%\}$	Ω_{DC}	$P\{r \geq 0\}$	$P\{r \geq r_{BH}\}$	Ω_{EV}	$P\{r_{TC} \geq 0\}$	$P\{r_{TC} \geq r_{BH}\}$	Ω_{TC}
0	0.975	261.221	0.912	0.914	39.415	0.681	0.693	3.882
0.0005	0.825	9.203	0.872	0.881	17.734	0.640	0.683	2.620
0.001	0.787	84.811	0.870	0.873	14.355	0.677	0.723	4.086
0.005	0.815	6.837	0.834	0.850	12.539	0.775	0.768	5.823
0.01	0.759	3.553	0.731	0.765	4.535	0.674	0.715	3.231

Probabilities of non-loosing money and Ω statistics for bootstrapped data.

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Performances of some standard rules

Trading rules	Performance measure	$k = 0$	$k = 0.0005$	$k = 0.001$	$k = 0.005$	$k = 0.01$
MA Oscillator	DC	52.21	50.87	50.41	50.94	43.59
	R	-0.088	-0.720	0.003	-0.032	0.067
	R^{tc}	-3.472	-3.223	-1.512	-0.345	-0.087
Variable length MA Oscillator	DC	50.04	48.99	49.18	50.00	48.72
	R	0.055	0.055	0.055	0.055	0.055
	R^{tc}	0.048	0.048	0.048	0.048	0.048
Filter Rule	DC	49.67	50.27	50.00	46.23	41.03
	R	-2.908	-2.908	-2.908	-2.908	-2.908
	R^{tc}	-2.953	-2.953	-2.953	-2.953	-2.953
Breakout Rule	DC	49.96	51.01	50.82	50.00	51.28
	R	-0.055	-0.055	-0.055	-0.055	-0.055
	R^{tc}	-0.062	-0.062	-0.062	-0.062	-0.062
Bollinger Band	DC	51.56	52.89	51.79	50.00	48.72
	R	1.309	1.795	1.122	0.055	0.055
	R^{tc}	1.275	1.761	1.102	0.048	0.048
Aroon Oscillator	DC	48.58	50.00	49.45	46.23	43.59
	R	-1.757	-1.327	-1.327	-1.298	-1.306
	R^{tc}	-1.797	-1.353	-1.353	-1.324	-1.333

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