Does frequency matter for intraday technical trading?*

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Abstract

This papers examines the profitability of two technical trading systems using an extensive sample of intraday data for the Russian Ruble US Dollar foreign exchange market. To accommodate for data snooping, the observed trading rule returns are tested for significance using the Superior Predictive Ability test (Hansen, 2005). The results indicate that regardless the benchmark or contract, technical trading profits seem much more present on a higher frequency basis. The adjustment for transaction costs however, wipe away most of the profits when trading at any frequency. Overall taking into account all adjustments, our analysis does not provide evidence that simple technical trading rules consistently generate superior returns in a context in which they should flourish. Neither is this the case when considering higher trading frequencies. However, we do find some evidence that from time to time technical trading rules generate superior returns. This finding becomes stronger for higher trading frequencies and the least liquid contract.

JEL classification: G11; G14; G17

KEY WORDS: Foreign Exchange, Technical Analysis, Intraday, Emerging Markets

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1 Introduction

Technical analysis is a trading decision method that uses past prices and volume with the objective of generating superior returns. Despite this ambitious goal, its utility is strongly contested by many academics (Malkiel, 1996) due to its head to head position with the efficient market hypothesis. Nevertheless, surveys have shown that technical analysis was and still is a popular technique in the financial industry. In a seminal paper Taylor and Allen (1992) found that 94% of foreign exchange dealers in London used some form of technical analysis over short horizons. Subsequent research confirmed this result for foreign exchange market participants on all relevant trading places (Menkhoff, 1997; Menkhoff and Taylor, 2007; Lui and Mole, 1998; Oberlechner, 2001; Cheung and Chinn, 2001; Cheung et al., 2004; Gehrig and Menkhoff, 2006). The fact that technical analysis is most heavily used on the foreign exchange market, is surprising at first sight, since this market is dominated by professional traders for whom we can expect not to rely on non-value creating tools. However, the market shows two characteristics making it prone for technical analysis: First, the share of short-term (inter-dealer) trading is significantly higher than in other financial markets (Lyons, 2001). Second, there is a plethora of competing fundamental models and this lack of a consensus model may be a reason for the popularity of technical analysis on foreign exchange markets (Menkhoff and Taylor, 2007).

The empirical literature on technical trading profitability has highlighted that technical trading rules are more profitable in emerging economies and on the foreign exchange market. Park and Irwin (2004) report almost 100 'modern' studies between 1988 and 2004 and find reported annual net profits of 10-30% for emerging markets and 5-10% for the foreign exchange market. The former could be attributed to lower market efficiency in emerging markets due to of less intense competition, a lower number of market participants (Lo, 2004) and the lack of sufficient publicly available information (Bessembinder and Chan, 1995). Another common argument supporting technical trading profitability is that technical analysis could indeed had merit in any market, however over time, its profitability decreased (Olson, 2004; Qi and Wu, 2006; Schulmeister, 2009). This decline in profitability could be the result of to a continuously increase in market efficiency or to environmental changes suggested by the adaptive market hypothesis (Lo, 2004).

Despite the primarily reported use on short term trading, the majority of empirical research on technical analysis is based on daily or lower frequency data whereas only 6 out of 92 reported modern studies used intraday data Park and Irwin (2004), each of these applied on the foreign exchange market. Furthermore, none of these studies have examined whether the applied trading frequency does affect the profitability

of technical trading rules.The shortage on empirical intraday technical trading studies thus provides an opportunity for research. Hence, this paper contributes to the literature by performing an intraday study on the Russian Ruble/US Dollar currency market. Given these three outlined characteristics – foreign exchange, emerging market and intraday – previous research suggests that technical trading should have merit in this setting. Therefore, this paper specifically tests for technical trading rule profitability based on the Superior Predictive Ability test (Hansen, 2005) for statistical inference. Moreover, to investigate a possible profitability shift towards higher frequencies, the tests were conducted on multiple frequencies which were constructed out of a tick-by-tick data set. Additionally to represent real trading as much as possible, we use the bid-ask spread for every time period to accommodate for transaction costs instead of relying on an ad-hoc imposed and fixed spread. Our contribution to the literature is thus fourfold. First, we analyze the profitability on the Russian Ruble/US Dollar exchange market and hence focus on an emerging economy's exchange rate, combining the two most promising markets in terms of profitable technical analysis, see above. Second, our data set covers a long time span of more than ten years and is tick-by-tick data, thus collected at the highest possible frequency. Therefore the data set allows us to (i) observe how the profitability evolved over time and (ii) to sample the data at any desired frequency. Third, different from most of the existing studies we can observe the best bid and ask prices, which makes it possible to apply the real transaction costs at any point in time, even if these are time-varying. Fourth and finally, we apply the recently developed statistical test by (Hansen, 2005) for statistical inference. In general, our analysis does not provide evidence that simple technical trading rules consistently generate superior returns in a context where they are argued to flourish. However, we do find some evidence that from time to time technical trading rules generate superior returns more prevalent for higher trading frequencies and less liquid contracts.

The remainder of the paper is organized as follows: section 2 reviews the literature on the profitability on emerging markets and foreign exchange markets with a focus on intraday studies, section 3 describes the data. Section 4 reveals the implemented trading rules and statistical tests, section 5 provides and discusses the found results and section 6 concludes.

2 Literature review: sources of profitability

2.1 Evidence from emerging markets

The adaptive market hypothesis of Lo (2004) postulates the degree of market efficiency as a result of the variety and amount of different kinds of market participants. The more diverse and the greater the amount, the fiercer the competition and the lower the profit opportunities. Therefore based on this theoretical framework, we expect that profit opportunities for technical trading rules are larger and more frequent in emerging markets as these are more exotic, less covered, and thus have a weaker competition among market participants. Empirically this has been shown by Bessembinder and Chan (1995) and Yu et al. (2013) who report that technical trading rules have predictive power in less developed markets. This finding is mainly attributed to due to the domination of few market participants, the lack of adequate publicly available information and to a lesser extent, by insider trading and heavier speculation. An additional argument for technical trading profitability is produced from more frequent and different motives behind exchange rate interventions in emerging markets which contribute to a more favorable environment in which technical trading could flourish (Martin, 2001). This argument is further supported by Sapp (2004) who finds that technical trading rules seem to be more profitable before and during central bank interventions. This finding could partly explain the more frequently observed profitability of technical analysis in emerging markets as shown by Park and Irwin (2004) who report that a majority of the empirical studies demonstrate the existence of profits in emerging markets in contrast to developed markets. Further evidence on profitability comes from Gunasekarage and Power (2001) for South-Asian stock markets, Lee et al. (2001) for Latin-American currencies, Ming-Ming and Siok-Hwa (2006) for Asian stock markets and Hatgioannides and Mesomeris (2007) for four Asian and four Latin-American stock markets. More recently, also Chang et al. (2014) find evidence for the profitability of moving average trading rules for emerging stock markets. Based on their findings they argue that less liquid stocks contribute to higher trading rule returns. Important for our research question their finding thus implies that technical trading rules add information and are part of the market information discounting process.

2.2 Evidence from foreign exchange markets

The foreign exchange market differs from other markets in the sense that the yearly turnover and liquidity are tremendously, non-profit maximizing agents are present and that professional traders are by far the

most important market participant (Sager and Taylor, 2006). Strikingly in foreign exchange markets, technical analysis is commonly known and used to some degree among professional investors (Taylor and Allen, 1992; Lui and Mole, 1998; Oberlechner, 2001; Gehrig and Menkhoff, 2006). Moreover, previous research reports that its importance has not decreased over time (Oberlechner, 2001; Gehrig and Menkhoff, 2006). This persistence of technical analysis suggests that technical trading strategies should have merit and yield superior yield returns even when transaction costs and risk are accounted for. The existence of profit opportunities for technical trading strategies has earlier been notified in the meta-study of (Park and Irwin, 2004) which highlights that a majority of the empirical studies do report the existence of profits in foreign exchange markets but not in stock markets. More specifically, the literature reports the profitability of moving average trading rules in foreign exchange markets (Chong and Ip, 2009; Szakmary and Mathur, 1997). As pointed out by LeBaron (1999), central bank interventions - more specifically leaning-against-the-wind interventions aimed at decreasing volatility and a gradual movement towards a new equilibrium level - could play some role for technical trading rule predictability and profitability. This delayed adjustment could provide the required profit opportunities from which trend-following trading rules profit (Szakmary and Mathur, 1997; Saacke, 2002). Others point out that positive technical trading returns are highest preceding bank interventions (Neely, 2002; Sapp, 2004) or are related to the likelihood of an intervention in the near future (Martin, 2001). However, (the likelihood of) an intervention may not necessarily spur technical trading returns as "*intervention reacts to the same strong short-run trends from which the trading rules have recently profited.*"(Neely, 2002, p230)

The empirical literature on the profitability of technical analysis in the foreign exchange market is however not fully conclusive. The large majority (63%) of performed studies does find evidence on significant positive returns - even when accounted for risk or transaction costs - in currency markets, others find (16%) mixed results, whereas a small fraction (21%) does not find any evidence (Park and Irwin, 2004). More interestingly for our research, Olson (2004) found that the profitability, both in absolute as in risk adjusted terms, of the moving average trading strategy steadily declined over time. While the strategy was still significantly profitable in the seventies, it was often found to be still profitable but insignificant in the eighties and eventually converged to zero returns in the nineties. Therefore, he argues that technical trading rule profits do exist but only temporarily as a result of investors searching for inefficiencies that disappear once they are detected and exploited.

2.3 Evidence from intraday studies

The use of technical analysis among foreign exchange dealers has been reported to be more important for short term forecasting purposes by numerous studies (Taylor and Allen, 1992; Lui and Mole, 1998; Oberlechner, 2001; Menkhoff and Taylor, 2007). Overall and interestingly for our research, the number of studies that investigate the profitability of technical trading rules on an intraday basis is rather limited. One study by Osler (2000) indicates possible profitability of technical trading rules by examining the power of support and resistance levels for several major currencies applied on a 1-minute frequency. The support and resistance levels published by six market participants showed that intraday price trends are significantly more interrupted at the reported support and resistance levels than at the artificial constructed levels. Other studies on foreign exchange markets do not find any evidence on the profitability of technical trading rules for the major currencies on lower intraday frequencies (Curcio et al., 1997; Neely and Weller, 2003). Neither was this the case for simple rules (Curcio et al., 1997) at a 1-hour interval, nor for more complex constructed based on the genetic algorithm at a 30-minute interval (Neely and Weller, 2003), moreover as expected both studies find a deterioration in results after incorporation of transactions costs. Similar results have been found for equity markets and future markets. For simple technical trading rules, previous research has shown that these are not profitable for equity markets, not even at a high frequency level. Tis lack of profitability has more specifically been shown for US equity markets at a 5-minute level (Marshall et al., 2008), for Australian and Developed Asian markets at a tick-by-tick level (Raj, 2000)and for Japanese equity markets at a 5-minute frequency (Yamamoto, 2012). Despite the absence of profitability reported in most studies above, Schulmeister (2009) studied the performance of simple technical trading rules in the S&P 500 spot and futures market on a daily and intraday basis for multiple years. Interestingly for our research, Schulmeister (2009) reports a gradual decline in performance for technical trading rules on a daily basis. Yet, on an intraday basis, technical trading rules seem still to be profitable, except for very recent periods which could indicate a further increase in stock market efficiency or that stock price trends are shifting to an even higher frequency.

3 Data

To assess the profitability of technical trading rules, we gathered tick-by-tick transaction data from the Moscow Interbank Currency Exchange (MICEX) ranging from January 2000 till June 2011 during the trading session taking place from 10 a.m. to 5.30 p.m. Moscow time. The data contains information on

date, time stamp to the second, price, dollar volume, ruble volume and security identity. This data meets strongly with the outlined environmental conditions, at the same time being foreign exchange, emerging market and intraday. Moreover, on the MICEX, market participants trading in the ruble-dollar currency pair can opt to trade in two different contracts: one with settlement today called 'TOD' and one with settlement tomorrow called 'TOM_old'. In 2004 a new contract was introduced with settlement tomorrow which we call 'TOM' as a replacement for the older contract with settlement tomorrow. The latter 2 series are closely related to one another, yet they are characterized by somewhat different underlying features. Therefore, we opted for treating them as separate contracts and not making a single time series from these.

In summary, we were able to extract three different yet very similar ruble-dollar price series. Specifically, TOD covers data from 2000 till 2011 whereas TOM only covers 2004 till 2011 and TOM_old only covers 2000-2004 as shown in table 1 which reports the descriptive statistics based on our hourly constructed data. Note that contracts with settlement tomorrow are much more frequently traded than the one with settlement today. For analysis purposes, we re-sampled the tick data at 10, 15, 30 and 60 minute frequencies and matched them with the prevalent quotes.

4 Methodology

4.1 Technical trading rules

4.1.1 Moving average trading rule

The moving average trading strategy is one of the most popular trading rules used in technical analysis (Taylor and Allen, 1992) while at the same the also one of the most vastly tested ones in academic research (Park and Irwin, 2004). The argument behind moving averages is that investors can exploit the underlying price trend shown by the trading rule by flattening price fluctuations over time. Even though many variants of moving average trading rules, such as simple moving averages, weighted moving average, and exponentially weighted moving averages, exist, for the sake of computational effort we restrict ourselves to simple moving average trading rules as shown below.

$$SMA_{r,t} = \frac{1}{r} \sum_{t=1}^{r} P_{t-r} \tag{1}$$

Table 1: Summary statistics

Panel A: TOD												
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
min [a]	-5.402	-4.012	-1.969	-7.217	-11.561	-7.052	-8.160	-7.323	-16.267	-21.393	-12.915	-8.653
max	17.209	5.094	3.927	6.807	6.203	8.968	5.454	5.334	23.058	33.519	20.945	14.889
mean	0.081	0.136	0.095	-0.340	-0.072	0.027	-0.077	-0.075	0.182	-0.153	0.031	-0.198
median	-0.053	0.003	0.003	-0.041	0.000	0.000	0.000	0.000	0.047	-0.083	0.000	0.000
std	1.968	0.980	0.673	1.624	1.247	1.431	1.163	1.141	2.919	3.631	2.665	2.208
skewness	3.349	1.086	1.219	0.051	-1.310	0.425	-1.345	-0.829	1.395	0.997	1.153	0.805
kurtosis	27.348	8.951	8.159	6.425	19.201	9.327	13.081	10.167	17.188	18.405	14.783	13.367
trading volume [b]	$35.62	$29.69	$30.05	$66.35	$804.83	$1,497.58	$1,728.80	$2,285.57	$2.618.17	$885.52	$766.81	$221.91
Panel B: TOM_old												
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
min	-22.734	-32.909	-17.332	-28.830	-3.972							
max	24.307	32.560	19.302	29.324	3.149							
mean	0.027	0.048	0.025	-0.047	-0.013							
median	0.000	0.000	0.000	0.000	0.000							
std	2.466	1.761	0.944	1.198	0.702							
skewness	1.208	-0.181	1.446	0.446	-0.422							
kurtosis	42.241	207.338	265.188	407.024	11.156							
trading volume	$1,299.54	$1,239.56	$1,195.07	$1,554.35	$914.89							
Panel C: TOM												
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
min					-6.862	-6.415	-8.116	-7.422	-15.988	-19.059	-11.458	-8.304
max					5.700	6.382	4.765	3.967	19.083	27.085	22.775	12.412
mean					-0.028	0.016	-0.045	-0.043	0.101	-0.104	0.022	-0.132
median					0.000	0.004	0.000	0.000	0.041	-0.080	0.000	-0.049
std					0.680	0.865	0.828	0.820	2.039	3.071	2.226	1.769
skewness					-2.672	0.047	-1.699	-1.006	1.166	0.591	0.997	0.730
kurtosis					34.116	13.870	20.441	13.346	20.229	14.766	17.539	13.220
trading volume					$2,867.48	3,618.25	$4,826.61	$5,538.96	$5,807.75	$2,582.10	$2,126.04	$970.74

[a] Log return * 1000
[b] In millions

$$LMA_{s,t} = \frac{1}{s} \sum_{t=1}^{s} P_{t-s} \tag{2}$$

With SMA and LMA being the short and long moving average respectively, P_t being the exchange rate at time time, r and s being the lag of the short and long moving average. For the given trading days short moving averages and long moving averages are computed as stated by equation 1 and 2. Moving averages trading rules imply that when the short moving average exceeds the long moving average the trader takes a long position. Contrary, when the short moving average is smaller than the long moving average, the trader takes a short position. The total number of considered moving average trading rules equals 4950 given that the maximum lag of the SMA and LMA is set at 99 and 100 respectively.

4.1.2 RSI

The RSI or relative strength indicator is an oscillator proposed by Wilder (1978) and is claimed to measure the relative strength of a security against itself. The indicator values of the RSI swing between 0 and 100 and are used to pinpoint overbought and oversold periods for a particular security. Whenever the RSI drops below a certain benchmark, for example 30, the security is considered being oversold and as a result a buy signal is generated. Likewise, whenever the RSI is above a certain threshold, for example 70, the security is considered overbought and as such a sell signal is generated. The following equations define the RSI.

$$RSI = 100 - 100/\left(1 + RS\right) \tag{3}$$

$$RS = AUC/ADC \tag{4}$$

With AUC (ADC) being the average up (down) closes of x periods. The RS is calculated using the average of a past period. Wilder (1978) suggests a 14-period average to smooth the time series. However, this seems to be an ad-hoc measure and it is not clear not clear why it should be preferred over other parameters. Additionally, the upper and lower levels used to measure overbought and oversold areas are ill defined as well, although upper levels of 70 and 80 are commonly cited together with lower levels of 20 or 30. In this

study we calculated the RSI with 100 different periods to average upon. These different relative strength indicators are set against 30 different upper and lower levels to generate buy and sell signals which leads to a total of 3069 different RSI trading models to be tested in the study.

4.2 Returns and transaction cost

The trading rule returns were calculated as the logarithmic difference of two consecutive trading prices possibly adjusted with the current observed spread conditional on having a trading signal.

$$r_{k,t+1} = \ln\left[P_{t+1} + h\hat{s}_t * D_{k,t+1}\right] - \ln\left[P_t + h\hat{s}_t * D_{k,t}\right] \tag{5}$$

Where $r_{k,t}$ is the kth at time t+1, P_t, the mid-price at time t, $\hat{hs}$ the observed and half of the spread which we use as our best estimate for the transaction cost and $D_{k,t}$ the kth trading rule trade direction at time t. Previous literature documented bid-ask spreads of around 0.05% and 0.08% for the German mark, the Japanese yen, the Swiss franc, and the British pound (Bessembinder, 1994). Cheung and Chinn (2001) also estimate the bid-ask spread to be 0.05% for the British pound and the Swiss franc and 0.03% for German mark and the Japanese yen. Also, Neely et al. (1997) report a 0.05% transaction cost to be realistic. First of all, our research however, covers a much less traded and liquid and more volatile currency pair deemed to have a larger spread. Secondly, instead of relying on a fixed spread over the whole sample, we preferred using a time-varying spread in order to replicate the real trading environment as much as possible. This thus reflects market improvements over the long run which contributes to lower spreads. Additionally, temporarily spread increases due to uncertainty or liquidity scarcity are also incorporated in the data. Trading signals that were generated during times of uncertainty are thus punished more by the spread.

4.3 RC and SPA test

The Reality Check Test by White (2000) tests whether the best model found has predictive power compared to a benchmark model taking into account the full universe of tested models. This test thus enables to quantify the amount of data snooping present. As a starting point, the methodology requires to formulate a performance statistic, $f_{k,t}$, as shown in equation 6 where b_t represents the benchmark return at time t, which is in turn compared to an estimate of the asymptotic distribution of the performance statistic.

$$f_{k,t} = r_{k,t} - b_t \tag{6}$$

Where $r_{k,t}$ is again the trading rule profit either with or without transaction cost adjustment. The null hypothesis states that the performance of the best rule found in the full universe of all tested rules in excess of the used benchmark is not greater than zero.

$$H_0 : \max_{k=1\to L} \{E(f_k)\} \leq 0 \tag{7}$$

The Reality Check directly constructs the asymptotic distribution by re-sampling the performance statistic using the stationary bootstrap proposed by Politis and Romano (1994) for each of the k models and define the computed series as $f^*_{k,t}$. An estimate of the distribution $N(0,\Omega)$ can be created by repeatedly re-sampling the performance statistic since $\sqrt{N} * \left(\overline{f}_{k,i} - \overline{f}_k\right) \xrightarrow{d} \sqrt{N} * \left(\overline{f}_{k,i} - \mu_k\right)$ when N $\longrightarrow \infty$ (Politis and Romano, 1994) and $\sqrt{N} * \left(\overline{f}_{k,i} - \mu_k\right)$ converges to $N(0,\Omega)$ when N $\longrightarrow \infty$ with $\mu_k = 0$ in conformance with the imposed least favorable configuration (White, 2000).

$$T^{RC} = \max_{k=1\to L} \left\{\sqrt{N} * \overline{f}_k\right\} \tag{8}$$

$$T^{RC}_i = \max_{k=1\to L} \left\{\sqrt{N} * \left(\overline{f}_{k,i} - \overline{f}_k\right)\right\} \tag{9}$$

White's Reality Check test offers a great improvement for mitigating data snooping when looking for a superior forecasting trading rule or model. However, Hansen (2005) argues that White's methodology incorporates some weaknesses. He argues that the p-values from the test can easily be inflated and manipulated by adding new, poor models to the universe of the tested models. Therefore, he suggests two modifications to the framework of the Reality Check test to accommodate this. The first modification encompasses studentizing the test statistic which allows comparing all the different models in terms of units of standard deviation.

$$T^{SPA} = \max\left[\max_{k=1\to L} \frac{\sqrt{N} * \overline{f_k}}{\hat{\sigma}_k}, 0\right] \tag{10}$$

The second modification constructs a null distribution dependent on the data to ensure that the influence from the poor alternative models is reduced .Therefore Hansen proposes to mitigate the influence of the worst performing trading rules by centering them around themselves while keeping the influence of better performing trading rules on the p-value. The separation between the worst and better performing trading rules is done by comparing the average return over the benchmark to a certain threshold as was proposed by Hansen (2005) and shown in equation 13.

$$T_i^{SPA} = \max\left[\max_{k=1\to L} \frac{\sqrt{N} * \overline{Z}_{k,i}}{\hat{\sigma_k}}, 0\right] \tag{11}$$

With

$$\overline{Z}_{k,i} = \overline{f}_{k,i} - h_x\left(\overline{f}_k\right) \tag{12}$$

Where h_x equals either, h_c, h_l, or h_u which represents the three different, consistent, lower bound, and upper bound, SPA p-value estimators.

$$h_c\left(\overline{f}_k\right) = \begin{cases} \overline{f}_k \text{if} \quad \overline{f}_k \geq -\sqrt{\frac{\hat{\sigma}_k^2}{N} * 2 * \log\log N} \\ 0 \text{ if} \quad \overline{f}_k \leq -\sqrt{\frac{\hat{\sigma}_k^2}{N} * 2 * \log\log N} \end{cases} \tag{13}$$

$$h_l\left(\overline{f}_k\right) = \max\left(0, \overline{f}_k\right) \tag{14}$$

$$h_u\left(\overline{f}_k\right) = 0 \tag{15}$$

Finally, we set the amount of bootstraps equal to 1000 and q equal to 0.2 which equals an average block length of 5 [1].

[1] Sullivan et al. (1999) used q equal to 0.1 and performed 500 bootstraps and report that results are insensitive on the choice of the block length parameter

5 Results

5.1 Zero return benchmark

We start our discussion with the found results, as shown in table 2, based on a zero return benchmark without incorporating any transaction costs. Here we have investigated the in-sample performance in terms of return, the amount of transactions made and the accompanying lower, upper and consistent p-values from the SPA-test. When analyzing this table we can state that an increase in the trading frequency at which technical trading rules are performed both has an advantageous effect on the realized return as on its significance. Specifically, we find that at a 60-minute trading frequency, the consistent p-values are significant at a 10% level for 5 out of 12 years. When we further increase the trading frequency up to 30-minute intervals, the number of significant values increase to 8 at a 10% from which 4 remain even significant at 1% significance level. At a 15-minute intervals, the results strengthen even more. In this case, a total of 9 technical trading rule returns are found that significantly have outperformed the zero return benchmark. At the highest frequency, a 10-minute trading frequency, again 9 technical trading rule returns are found being significantly larger than 0 at a 10% significance level. Moreover, the previous found result further improve in terms of the further reduction of the p-values. In absence of transaction costs, we thus find that technical trading rules can exploit the market's incomplete and lagging information processing, especially in very short terms. Additionally we can state that in absence of transaction costs, the relative strength indicator tends perform slightly better than the moving average trading rule. Remarkably, the results indicate that an imposed 60-40 level, or close-by, tends to perform well for any trading frequency in many years.

Besides the found increase in profitability and significance of the trading rules, we also find an increasing trend in the the amount of performed transactions each time the trading frequency is shortened. Therefore, the results could be biased and not representative for a real trading environment. To accommodate this problem, we apply a transaction cost gathered from the observed bid-ask spread in our subsequent analysis. Overall we find that, incorporating the transaction costs deteriorate the best trading rule return to a great extent, as shown in table 3 which reports the best trading rule with its accompanying return, number of transactions and its lower, upper and consistent p-values from the SPA-test. As expected, imposing transactions costs estimated based on the quoted spread largely reduce the trading rule returns. Specifically, we find at a 60-minute trading frequency that the consistent p-values are significant at a 10% level for 1 out of 12 years. When we increase the frequency up to 30-minute intervals, the number of

significant values increase to 3 at 10% significance level, whereas on a 15-minute intervals, the results deteriorate. In this case, only 2 technical trading rules are found having significantly outperformed the zero return benchmark. At the 10-minute trading level, the results improve again with a total of 4 significant trading rule returns. We thus can conclude that the lack of incorporating transaction costs in our previous analysis mostly explains the previous found increase in significant returns. Overall, the results are far less outspoken compared the the analysis above, and technical trading rule returns do not yield significantly better returns in most cases. Nevertheless, we do find that on occasion technical trading rules do yield superior returns which is more pronounced for shorter horizons. With respect to the selected trading rule, the relative strength index remains the mostly selected trading rule. However, compared to the results without transactions costs, trading rules which generate less trading signals are now mostly selected despite the considered trading frequency. This finding remains when analyzing higher frequencies, nevertheless, higher frequencies tend to provide somewhat more active trading rules.

5.2 Robustness check

5.2.1 Buy and hold benchmark

As there is no agreement in the literature (Park and Irwin, 2004) which benchmark to use, we additionally apply a second benchmark as the previous found results may be sensitive to the chosen criterion. For our subsequent analysis we opt to apply the widely used buy-and-hold benchmark to test the robustness of the reported results. Our analysis is reported in table 4 which again reports the best found trading rule with its accompanying returns, the number of transactions and its lower, upper and consistent p-values from the SPA-test. The results, without transaction cost adjustments based on this benchmark are in general in line with those of the zero return benchmark. Here again we find that higher trading frequencies tend to have an advantageous effect on the realized return and on its significance. Specifically, we find that at a 60-minute trading frequency, the consistent p-values are significant at a 10% level for 6 out of 12 years. When we further increase the trading frequency up to 30-minute intervals, the number of significant values increase to 7 at a 10% from which 4 remain even significant at 1% significance level. At a 15-minute intervals, the results strengthen even more. In this case, a total of 8 technical trading rule returns are found that significantly have outperformed the zero return benchmark. At the highest frequency, a 10-minute trading frequency, 10 technical trading rule returns are found being significantly superior at a 10% significance level. Moreover, the previous found result further improve in terms of the

further reduction of the p-values.

Both the trading rule returns as the performed transactions of the best found trading rule decline when accommodating for transaction costs as can be seen in table 5. The consistent p-values are significant at a 10% significance level for 4 out of 12 years. At 30-minute intervals, the number of significant values deteriorate to only 3 significant returns at a 10% level. When increasing the frequency to 15-minute intervals the results slightly improve to a total of 4 significant returns . At a 10-minute level, the previous found result improves to a total of 6 significant found results at a 10% level. These results confirm that the benchmark choice does not greatly alter our previous found overall conclusion with respect to the increase in the profitability, the significance of the trading rules as well as the performed transactions when higher frequencies are covered. These findings thus indicates that the found results with respect to the trading frequency level are robust irrespective of the chosen benchmark.

5.2.2 Contract type

Additionally we further check whether the results remain robust, in terms of transaction costs and benchmark choice, when applied to other contracts that are traded on the MICEX. Starting with the contract 'TOM_old' which was traded from 2000 till 2004, we do find similar results as reported before. In absence of transaction costs and based on the zero return benchmark, we observe a large increase in the realized return as in the amount of performed transactions. On top of that, we observe that already at the lowest frequency, 4 out of 5 results are already significant. However, transaction cost adjustments alter the results to a large extent. In this case, none of the trading rule returns are found being significantly superior except in the year 2001 in case of the two highest trading frequencies. These findings remain even when we apply the alternative buy-and-hold benchmark [2].

The results are similar in case we analyze the results for another alternative contract 'TOM'. Again, irrespective of the chosen benchmark, we find significant trading rule returns for most years which become more pronounced at higher trading frequencies. The effect of the imposed transactions costs is again similar to what is observed before. Transaction costs lead to the selection of less active trading rules and largely decrease the profitability and significance. In case of the zero return benchmark, we do not find evidence that technical trading rules can yield superior returns. This lack of profitability may be devoted to the amount of trading volume related to this contract. As this is the most frequently traded contract,

[2]Results are available upon request.

prices may adjust more quickly on news arrivals compared to the other contracts. As trading rules are lagging indicators, they may become to slow and no longer able to exploit delayed information processing.

5.2.3 Lag length sensitivity

In a last step, we investigate whether the choice of the block length affects our results based on our baseline block length. We therefore test for robustness by applying ten different block lengths on hourly data evaluated at two different benchmarks both with and without accounting for transaction costs.Table 10, 11, 12 and 13 report the consistent, upper and lower bound SPA p-values using different block lengths. For any given year based on the zero return benchmark without considering transaction costs, the found consistent p-values remain fairly close to one another and only differ by a maximum of 5 percentage points in the year 2010. The adjustment for transactions costs nor a change in the chosen benchmark alter our previous findings. The reported p-values thus remain robust for any given year and for any benchmark. Overall, our results support the finding that the found p-values are robust for any chosen block length. The robustness regarding the lag length thus corroborates with the results by Sullivan et al. (1999) and Qi and Wu (2006) who applied alternative smoothing parameters of 0.01, 0.1 and 0.5 and of 0.1 and 1 respectively.

6 Conclusion

Professional investors widely put their faith in technical analysis to obtain superior returns (Taylor and Allen, 1992; Lui and Mole, 1998; Cheung and Chinn, 2001; Menkhoff and Taylor, 2007), yet evidence on the profitability in the literature is not fully conclusive. Previous evidence suggest that technical trading has more merit in emerging markets, in foreign exchange markets (Park and Irwin, 2004) and in ever higher frequencies (Schulmeister, 2009). First, we contribute to the literature by incorporating all three aspects at the same time. Second, we use a time-varying transaction cost instead of relying on a fixed estimate. Third, we assess the profitability of technical trading rules on different trading frequencies. By assessing both the moving average and relative strength indicator trading rules against both the buy-and-hold and zero return benchmark while accounting for data snooping and transaction costs on three separate yet highly similar contracts. In our study we conclude that initially, the results that a higher frequency level provides a better opportunity for technical trading strategies for all the investigated contracts. However, most of the increase in returns seems to be the result of much more frequent trading. As a result, the trading rule

returns deteriorate and are found to not significantly outperform their benchmark when accounted for transaction costs. This is especially the case for the second (TOM_old) and third (TOM) contract which are both more frequently traded and more liquid. Overall we conclude that simple technical trading rules do not consistently generate superior returns in a context where they are argued to flourish. However, we do find some evidence that from time to time technical trading rules generate superior returns. This finding becomes stronger for higher trading frequencies and the least liquid contract (TOD). A possible explanation could be the lower liquidity and less frequent trading leading to a slower price discovery process for this contract. Hence future research could further investigate the role of liquidity and the effect of order flow on market efficiency on technical trading profitability.

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7 Appendix

Table 2: Overview results trading rules

TOD-NC-ZB	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Trading rule	RSI	MA	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	RSI	RSI
	Parameters	18,70,30	75,76	2,63,37	17,29	2,61,39	2,65,35	2,70,30	2,62,38	2,73	3,5	41,65,35	7,84,16
	Transactions	7	9	267	9	509	591	497	491	37	379	25	17
60 minutes	Return	10,23%	6,03%	3,44%	6,49%	10,38%	19,83%	9,32%	10,57%	24,48%	36,58%	23,69%	10,30%
	c	0,195	0,029	0,037	0,191	0,010	0,000	0,200	0,104	0,203	0,094	0,225	0,517
	l	0,169	0,022	0,029	0,146	0,010	0,000	0,162	0,080	0,147	0,075	0,191	0,454
	u	0,195	0,032	0,044	0,191	0,010	0,000	0,204	0,109	0,204	0,094	0,226	0,517
	Trading rule	RSI	MA	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	18,70,30	75,76	2,63,37	31,57	2,62,38	2,63,37	2,72,28	2,60,40	11,41	6,8	4,9	4,5
	Transactions	7	9	279	9	1015	1253	1023	1159	87	581	535	449
30 minutes	Return	10,23%	6,03%	3,69%	8,75%	19,04%	26,44%	14,25%	11,15%	22,72%	49,84%	27,14%	13,30%
	c	0,188	0,030	0,022	0,022	0,000	0,000	0,006	0,083	0,348	0,003	0,160	0,250
	l	0,165	0,022	0,019	0,015	0,000	0,000	0,003	0,070	0,255	0,002	0,134	0,204
	u	0,188	0,031	0,023	0,022	0,000	0,000	0,006	0,085	0,349	0,003	0,163	0,250
	Trading rule	RSI	RSI	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	2,60,40	2,60,40	2,60,40	61,100	2,60,40	3,60,40	2,68,32	2,62,38	75,76	19,20	6,18	9,10
	Transactions	555	675	619	9	2163	2125	2399	2505	255	765	535	669
15 minutes	Return	12,76%	11,94%	6,97%	9,40%	32,16%	40,45%	20,12%	18,69%	21,85%	48,75%	30,02%	12,93%
	c	0,167	0,000	0,000	0,020	0,000	0,000	0,000	0,000	0,459	0,005	0,090	0,379
	l	0,152	0,000	0,000	0,015	0,000	0,000	0,000	0,000	0,385	0,005	0,073	0,312
	u	0,168	0,000	0,000	0,021	0,000	0,000	0,000	0,000	0,460	0,005	0,091	0,379
	Trading rule	RSI	RSI	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	2,61,39	2,60,40	2,60,40	2,88	2,60,40	2,60,40	2,62,38	2,64,36	47,48	28,29	10,24	17,32
	Transactions	901	1037	1007	23	3319	4495	4265	3821	619	945	631	163
10 minutes	Return	20,58%	16,81%	11,60%	8,56%	58,53%	68,66%	37,94%	28,05%	21,40%	52,54%	29,65%	14,71%
	c	0,000	0,000	0,000	0,058	0,000	0,000	0,000	0,000	0,558	0,004	0,110	0,197
	l	0,000	0,000	0,000	0,041	0,000	0,000	0,000	0,000	0,437	0,003	0,088	0,155
	u	0,000	0,000	0,000	0,062	0,000	0,000	0,000	0,000	0,560	0,004	0,111	0,202

This table provides based on a zero return benchmark without considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the first traded contract over all considered trading frequencies.

Table 3: Overview results trading rules

TOD-C-ZB	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Trading rule	MA	MA	MA	MA	MA	RSI	RSI	MA	MA	RSI	RSI	RSI
	Parameters	81,85	44,63	30,62	17,29	58,76	2,77,23	51,71,29	46,91	2,73	68,68,32	41,65,35	7,84,16
	Transactions	23	5	5	9	19	497	1	11	37	5	25	17
60 minutes	Return	5,83%	5,69%	2,23%	6,21%	5,04%	10,01%	8,25%	10,06%	23,53%	33,82%	23,18%	9,63%
	c	0,891	0,065	0,420	0,239	0,386	0,296	0,336	0,151	0,262	0,172	0,275	0,603
	l	0,757	0,033	0,255	0,166	0,219	0,177	0,217	0,109	0,170	0,135	0,223	0,475
	u	0,936	0,152	0,673	0,241	0,662	0,389	0,415	0,184	0,265	0,174	0,290	0,617
	Trading rule	MA	MA	MA	MA	RSI	RSI	RSI	RSI	MA	RSI	RSI	RSI
	Parameters	80,89	44,63	30,62	31,57	18,90,10	3,74,26	13,90,10	15,86,14	11,41	99,66,34	7,90,10	13,90,10
	Transactions	23	5	5	9	5	659	1	9	87	9	57	1
30 minutes	Return	5,47%	5,69%	2,23%	8,47%	5,74%	14,56%	6,10%	10,38%	20,22%	37,15%	23,12%	7,12%
	c	0,928	0,064	0,425	0,042	0,477	0,027	0,865	0,135	0,513	0,131	0,380	0,969
	l	0,810	0,032	0,231	0,021	0,236	0,020	0,660	0,082	0,333	0,097	0,289	0,870
	u	0,966	0,146	0,702	0,044	0,816	0,070	0,946	0,196	0,547	0,134	0,411	0,983
	Trading rule	RSI	MA	MA	MA	RSI	RSI	RSI	RSI	MA	MA	RSI	RSI
	Parameters	20,66,34	16,53	66,100	61,100	21,90,10	8,61,39	18,90,10	27,81,19	24,83	12,15	8,83,17	33,71,29
	Transactions	27	13	5	9	5	889	1	9	87	669	217	17
15 minutes	Return	4,88%	4,64%	2,97%	9,12%	5,59%	20,65%	7,03%	10,32%	18,58%	32,39%	19,77%	9,26%
	c	0,982	0,399	0,292	0,034	0,583	0,001	0,771	0,160	0,681	0,290	0,657	0,825
	l	0,837	0,217	0,166	0,014	0,307	0,001	0,566	0,077	0,447	0,206	0,503	0,585
	u	0,992	0,766	0,701	0,065	0,961	0,006	0,937	0,335	0,745	0,322	0,780	0,908
	Trading rule	RSI	MA	MA	RSI	RSI	RSI	RSI	RSI	MA	MA	RSI	MA
	Parameters	22,65,35	51,89	32,100	12,90,10	7,62,38	8,60,40	11,64,36	43,75,25	30,97	16,25	18,83,17	17,32
	Transactions	55	17	11	1	813	1447	753	9	123	505	45	163
10 minutes	Return	5,49%	5,47%	3,26%	8,44%	9,87%	21,01%	10,67%	11,61%	18,18%	32,99%	20,59%	8,08%
	c	0,985	0,316	0,280	0,067	0,066	0,001	0,171	0,084	0,742	0,257	0,602	0,925
	l	0,829	0,143	0,137	0,033	0,029	0,001	0,109	0,050	0,498	0,178	0,410	0,691
	u	0,999	0,778	0,777	0,155	0,628	0,030	0,503	0,264	0,830	0,285	0,758	0,984

This table provides based on a zero return benchmark with considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the first traded contract over all considered trading frequencies.

Table 4: Overview results trading rules

TOD-NC-BHB	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Trading rule	RSI	MA	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	RSI	RSI
	Parameters	18,70,30	75,76	2,63,37	17,29	2,61,39	2,65,35	2,70,30	2,62,38	2,73	3,5	41,65,35	7,84,16
	Transactions	7	9	267	9	509	591	497	491	37	379	25	17
60 minutes	Return	10,23%	6,03%	3,44%	6,49%	10,38%	19,83%	9,32%	10,57%	24,48%	36,58%	23,69%	10,30%
	c	0,292	1,000	0,755	0,036	0,008	0,026	0,025	0,014	0,929	0,046	0,372	0,188
	l	0,278	0,964	0,450	0,036	0,007	0,017	0,025	0,014	0,739	0,044	0,328	0,187
	u	0,292	1,000	0,814	0,036	0,008	0,027	0,025	0,014	0,931	0,046	0,372	0,188
	Trading rule	RSI	MA	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	18,70,30	75,76	2,63,37	31,57	2,62,38	2,63,37	2,72,28	2,60,40	11,41	6,8	4,9	4,5
	Transactions	7	9	279	9	1015	1253	1023	1159	87	581	535	449
30 minutes	Return	10,23%	6,03%	3,69%	8,75%	19,04%	26,44%	14,25%	11,15%	22,72%	49,84%	27,14%	13,30%
	c	0,302	0,999	0,661	0,004	0,002	0,001	0,005	0,006	0,967	0,007	0,373	0,077
	l	0,287	0,961	0,372	0,004	0,002	0,000	0,005	0,006	0,814	0,007	0,334	0,076
	u	0,302	0,999	0,726	0,004	0,002	0,001	0,005	0,006	0,967	0,007	0,373	0,077
	Trading rule	RSI	RSI	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	2,60,40	2,60,40	2,60,40	61,100	2,60,40	3,60,40	2,68,32	2,62,38	75,76	19,20	6,18	9,10
	Transactions	555	675	619	9	2163	2125	2399	2505	255	765	535	669
15 minutes	Return	12,76%	11,94%	6,97%	9,40%	32,16%	40,45%	20,12%	18,69%	21,85%	48,75%	30,02%	12,93%
	c	0,232	0,116	0,086	0,002	0,000	0,000	0,000	0,000	0,975	0,004	0,326	0,090
	l	0,216	0,024	0,027	0,002	0,000	0,000	0,000	0,000	0,847	0,004	0,280	0,090
	u	0,232	0,172	0,162	0,002	0,000	0,000	0,000	0,000	0,976	0,004	0,327	0,090
	Trading rule	RSI	RSI	RSI	MA	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	2,61,39	2,60,40	2,60,40	2,88	2,60,40	2,60,40	2,62,38	2,64,36	47,48	28,29	10,24	17,32
	Transactions	901	1037	1007	23	3319	4495	4265	3821	619	945	631	163
10 minutes	Return	20,58%	16,81%	11,60%	8,56%	58,53%	68,66%	37,94%	28,05%	21,40%	52,54%	29,65%	14,71%
	c	0,021	0,018	0,001	0,001	0,000	0,000	0,000	0,000	0,978	0,000	0,381	0,046
	l	0,021	0,007	0,000	0,001	0,000	0,000	0,000	0,000	0,892	0,000	0,321	0,046
	u	0,021	0,028	0,001	0,001	0,000	0,000	0,000	0,000	0,980	0,000	0,382	0,046

This table provides based on a buy-and-hold benchmark without considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the first traded contract over all considered trading frequencies.

Table 5: Overview results trading rules

TOD-C-BHB	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Trading rule	MA	MA	MA	MA	MA	RSI	RSI	MA	MA	RSI	RSI	RSI
	Parameters	81,85	44,63	30,62	17,29	58,76	2,77,23	51,71,29	46,91	2,73	68,68,32	41,65,35	7,84,16
	Transactions	23	5	5	9	19	497	1	11	37	5	25	17
60 minutes	Return	5,83%	5,69%	2,23%	6,21%	5,04%	10,01%	8,25%	10,06%	23,53%	33,82%	23,18%	9,63%
	c	0,655	1,000	1,000	0,049	0,125	0,689	0,061	0,020	0,939	0,065	0,388	0,199
	l	0,565	0,923	0,900	0,049	0,098	0,497	0,059	0,019	0,727	0,062	0,337	0,190
	u	0,725	1,000	1,000	0,049	0,155	0,739	0,064	0,021	0,950	0,065	0,389	0,199
	Trading rule	MA	MA	MA	MA	RSI	RSI	RSI	RSI	MA	RSI	RSI	RSI
	Parameters	80,89	44,63	30,62	31,57	18,90,10	3,74,26	13,90,10	15,86,14	11,41	99,66,34	7,90,10	13,90,10
	Transactions	23	5	5	9	5	659	1	9	87	9	57	1
30 minutes	Return	5,47%	5,69%	2,23%	8,47%	5,74%	14,56%	6,10%	10,38%	20,22%	37,15%	23,12%	7,12%
	c	0,670	1,000	1,000	0,006	0,281	0,276	0,169	0,014	0,981	0,033	0,519	0,305
	l	0,601	0,910	0,914	0,006	0,217	0,185	0,154	0,012	0,774	0,031	0,441	0,283
	u	0,745	1,000	1,000	0,006	0,442	0,377	0,184	0,015	0,985	0,033	0,537	0,309
	Trading rule	RSI	MA	MA	MA	RSI	RSI	RSI	RSI	MA	MA	RSI	RSI
	Parameters	20,66,34	16,53	66,100	61,100	21,90,10	8,61,39	18,90,10	27,81,19	24,83	12,15	8,83,17	33,71,29
	Transactions	27	13	5	9	5	889	1	9	87	669	217	17
15 minutes	Return	4,88%	4,64%	2,97%	9,12%	5,59%	20,65%	7,03%	10,32%	18,58%	32,39%	19,77%	9,26%
	c	0,740	1,000	0,999	0,002	0,305	0,040	0,131	0,018	0,991	0,074	0,695	0,231
	l	0,625	1,000	0,863	0,002	0,222	0,020	0,106	0,016	0,842	0,070	0,583	0,194
	u	0,780	1,000	1,000	0,002	0,595	0,107	0,170	0,023	0,993	0,074	0,739	0,245
	Trading rule	RSI	MA	MA	RSI	RSI	RSI	RSI	RSI	MA	MA	RSI	MA
	Parameters	22,65,35	51,89	32,100	12,90,10	7,62,38	8,60,40	11,64,36	43,75,25	30,97	16,25	18,83,17	17,32
	Transactions	55	17	11	1	813	1447	753	9	123	505	45	163
10 minutes	Return	5,49%	5,47%	3,26%	8,44%	9,87%	21,01%	10,67%	11,61%	18,18%	32,99%	20,59%	8,08%
	c	0,744	1,000	1,000	0,004	0,081	0,035	0,034	0,008	1,000	0,063	0,676	0,294
	l	0,629	1,000	1,000	0,004	0,053	0,025	0,028	0,006	1,000	0,059	0,546	0,234
	u	0,802	1,000	1,000	0,006	0,386	0,164	0,067	0,021	1,000	0,064	0,734	0,353

This table provides based on a buy-and-hold benchmark with considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the first traded contract over all considered trading frequencies.

Table 6: Overview results trading rules

TOM_old-NC-ZB	Year	2000	2001	2002	2003	2004
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	2,62,38	2,60,40	2,60,40	2,61,39	2,62,38
	Transactions	961	935	1233	1113	525
60 minutes	Return	114,17%	30,54%	20,17%	10,76%	6,67%
	c	0,000	0,001	0,001	0,304	0,004
	l	0,000	0,001	0,001	0,238	0,002
	u	0,000	0,001	0,001	0,310	0,004
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	2,62,38	2,60,40	2,60,40	2,61,39	2,60,40
	Transactions	1959	1701	2295	2321	1111
30 minutes	Return	223,21%	46,36%	28,01%	41,16%	15,44%
	c	0,000	0,001	0,000	0,002	0,000
	l	0,000	0,001	0,000	0,002	0,000
	u	0,000	0,001	0,000	0,002	0,000
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	2,60,40	2,60,40	2,60,40	2,60,40	2,60,40
	Transactions	3653	2591	3589	3917	1925
15 minutes	Return	430,12%	59,76%	46,05%	59,07%	20,34%
	c	0,000	0,000	0,000	0,000	0,000
	l	0,000	0,000	0,000	0,000	0,000
	u	0,000	0,000	0,000	0,000	0,000
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	2,61,39	2,60,40	2,60,40	2,61,39	2,60,40
	Transactions	4857	3141	4343	50195981	2559
10 minutes	Return	544,39%	86,96%	51,74%	73,79%	28,70%
	c	0,000	0,000	0,000	0,000	0,000
	l	0,000	0,000	0,000	0,000	0,000
	u	0,000	0,000	0,000	0,000	0,000

This table provides based on a zero return benchmark without considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the second traded contract over all considered trading frequencies.

Table 7: Overview results trading rules

TOM_old-C-ZB	Year	2000	2001	2002	2003	2004
	Trading rule	RSI	RSI	RSI	RSI	MA
	Parameters	27,68,32	20,78,22	4,90,10	65,69,31	29,69
	Transactions	9	5	37	5	21
60 minutes	Return	5,50%	11,46%	4,65%	10,17%	2,05%
	c	1,000	0,274	0,629	0,398	0,917
	l	0,654	0,094	0,269	0,194	0,689
	u	1,000	0,462	0,857	0,485	0,972
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	8,90,10	5,71,29	10,74,26	100,65,35	93,67,33
	Transactions	5	389	97	7	1
30 minutes	Return	1,05%	14,00%	5,29%	12,23%	2,64%
	c	1,000	0,154	0,531	0,441	0,896
	l	0,885	0,138	0,269	0,114	0,631
	u	1,000	0,525	0,905	0,612	0,984
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	22,76,24	3,84,16	3,85,15	24,79,21	35,74,26
	Transactions	13	417	581	9	1
15 minutes	Return	1,33%	16,37%	7,76%	13,81%	2,94%
	c	1,000	0,097	0,213	0,357	0,867
	l	0,851	0,096	0,202	0,142	0,504
	u	1,000	0,490	0,808	0,643	0,991
	Trading rule	RSI	RSI	RSI	RSI	RSI
	Parameters	13,88,12	4,76,24	6,88,12	44,70,30	8,90,10
	Transactions	9	557	65	13	9
10 minutes	Return	-2,08%	22,40%	8,22%	14,79%	3,69%
	c	1,000	0,042	0,193	0,265	0,623
	l	1,000	0,041	0,187	0,121	0,366
	u	1,000	0,246	0,793	0,628	0,977

This table provides based on a zero return benchmark with considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the second traded contract over all considered trading frequencies.

Table 8: Overview results trading rules

TOM-NC-ZB	Year	2004	2005	2006	2007	2008	2009	2010	2011
	Trading rule	RSI	MA	RSI	RSI	MA	MA	RSI	MA
	Parameters	2,61,39	48,64	100,66,34	11,89,11	6,47	3,5	82,60,40	3,5
	Transactions	1339	55	3	21	83	587	43	269
60 minutes	Return	17,07%	7,54%	7,66%	10,77%	21,59%	37,27%	25,43%	13,35%
	c	0,000	0,724	0,560	0,089	0,343	0,089	0,170	0,256
	l	0,000	0,639	0,464	0,071	0,248	0,072	0,149	0,208
	u	0,000	0,725	0,560	0,089	0,345	0,089	0,170	0,256
	Trading rule	RSI	RSI	RSI	RSI	MA	MA	MA	MA
	Parameters	2,61,39	2,60,40	2,63,37	19,84,16	16,40	9,15	9,28	5,11
	Transactions	2719	2439	2327	13	157	367	249	265
30 minutes	Return	33,99%	11,43%	16,98%	10,03%	22,77%	43,63%	23,10%	14,15%
	c	0,000	0,127	0,001	0,199	0,313	0,028	0,417	0,235
	l	0,000	0,099	0,001	0,158	0,233	0,021	0,364	0,186
	u	0,000	0,129	0,001	0,201	0,314	0,028	0,417	0,236
	Trading rule	RSI	RSI	RSI	RSI	MA	MA	RSI	RSI
	Parameters	2,60,40	2,60,40	2,60,40	2,60,40	52,54	25,29	2,64,36	2,60,40
	Transactions	5165	5209	5343	5031	611	561	4555	2029
15 minutes	Return	67,73%	37,43%	39,57%	30,22%	23,71%	47,88%	43,96%	23,48%
	c	0,000	0,000	0,000	0,000	0,288	0,018	0,000	0,001
	l	0,000	0,000	0,000	0,000	0,242	0,013	0,000	0,001
	u	0,000	0,000	0,000	0,000	0,290	0,018	0,000	0,001
	Trading rule	RSI	RSI	RSI	RSI	MA	RSI	RS5165I	RSI
	Parameters	2,60,40	2,60,40	2,60,40	2,60,40	77,88	2,65,35	2,60,40	2,60,40
	Transactions	7311	8311	8335	7989	341	5673	7381	3175
10 minutes	Return	97,22%	65,30%	63,02%	48,90%	23,94%	57,87%	61,19%	35,89%
	c	0,000	0,000	0,000	0,000	0,299	0,000	0,000	0,000
	l	0,000	0,000	0,000	0,000	0,243	0,000	0,000	0,000
	u	0,000	0,000	0,000	0,000	0,302	0,000	0,000	0,000

This table provides based on a zero return benchmark without considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the third traded contract over all considered trading frequencies.

Table 9: Overview results trading rules

TOM-C-ZB	Year	2004	2005	2006	2007	2008	2009	2010	2011
	Trading rule	RSI	RSI	RSI	RSI	MA	RSI	RSI	RSI
	Parameters	78,72,28	94,60,40	100,66,34	11,89,11	7,44	90,64,36	82,60,40	20,90,10
	Transactions	5	29	3	21	75	5	43	1
60 minutes	Return	5,54%	7,19%	7,57%	10,67%	19,52%	30,90%	24,71%	7,17%
	c	0,478	0,725	0,493	0,114	0,476	0,301	0,222	0,955
	l	0,210	0,460	0,317	0,071	0,323	0,222	0,147	0,874
	u	0,771	0,813	0,618	0,156	0,512	0,305	0,236	0,963
	Trading rule	RSI	RSI	RSI	RSI	MA	MA	MA	RSI
	Parameters	72,74,26	64,68,32	14,90,10	19,84,16	12,89	9,15	9,28	13,90,10
	Transactions	5	17	1	13	77	367	249	1
30 minutes	Return	6,20%	8,18%	7,14%	9,94%	20,52%	34,52%	15,96%	7,52%
	c	0,363	0,533	0,683	0,197	0,432	0,185	0,900	0,959
	l	0,121	0,225	0,391	0,076	0,248	0,121	0,740	0,818
	u	0,842	0,743	0,883	0,317	0,518	0,202	0,934	0,981
	Trading rule	RSI	RSI	RSI	RSI	MA	MA	MA	RSI
	Parameters	37,79,21	91,65,35	17,90,10	20,82,18	30,78	25,29	30,91	50,66,34
	Transactions	5	17	1	13	159	561	161	17
15 minutes	Return	3,93%	5,67%	7,80%	13,39%	18,11%	34,97%	16,43%	10,43%
	c	0,855	0,936	0,501	0,015	0,621	0,249	0,869	0,745
	l	0,409	0,639	0,204	0,006	0,453	0,184	0,604	0,508
	u	0,999	0,996	0,887	0,113	0,751	0,298	0,955	0,884
	Trading rule	RSI	RSI	RSI	RSI	MA	MA	RSI	MA
	Parameters	26,90,10	6,90,10	22,90,10	82,66,34	38,92	25,43	13,90,10	22,44
	Transactions	1	109	1	13	211	387	9	167
10 minutes	Return	3,87%	6,09%	7,47%	9,99%	18,13%	33,07%	20,21%	9,73%
	c	0,860	0,840	0,479	0,164	0,660	0,280	0,608	0,792
	l	0,531	0,659	0,246	0,044	0,426	0,200	0,389	0,481
	u	0,999	0,995	0,957	0,633	0,817	0,367	0,827	0,954

This table provides based on a zero return benchmark with considering transaction costs the best trading rule, its corresponding parameters, returns and consistent, lower and upper p-values for the third traded contract over all considered trading frequencies.

Table 10: Overview robustness p-values

	year / block length	1	2	3	4	5	6	7	8	9	10
c	2000	0,200	0,189	0,205	0,212	0,203	0,194	0,191	0,199	0,193	0,209
	2001	0,030	0,024	0,028	0,031	0,032	0,031	0,032	0,026	0,033	0,030
	2002	0,041	0,036	0,037	0,038	0,045	0,037	0,041	0,044	0,037	0,036
	2003	0,179	0,187	0,169	0,172	0,184	0,175	0,186	0,183	0,174	0,185
	2004	0,017	0,011	0,013	0,008	0,013	0,010	0,011	0,012	0,016	0,012
	2005	0,000	0,000	0,001	0,001	0,000	0,000	0,001	0,001	0,000	0,000
	2006	0,196	0,201	0,195	0,177	0,190	0,211	0,191	0,213	0,211	0,193
	2007	0,118	0,103	0,104	0,109	0,115	0,122	0,118	0,108	0,094	0,127
	2008	0,215	0,212	0,201	0,218	0,232	0,221	0,215	0,211	0,220	0,227
	2009	0,102	0,095	0,082	0,096	0,111	0,101	0,099	0,092	0,106	0,106
	2010	0,266	0,220	0,237	0,237	0,249	0,248	0,254	0,248	0,248	0,270
	2011	0,509	0,501	0,505	0,504	0,536	0,518	0,526	0,505	0,510	0,505
l	2000	0,175	0,171	0,190	0,192	0,181	0,175	0,172	0,181	0,168	0,185
	2001	0,024	0,018	0,023	0,026	0,025	0,024	0,026	0,019	0,027	0,021
	2002	0,034	0,031	0,029	0,030	0,035	0,029	0,031	0,033	0,027	0,028
	2003	0,143	0,153	0,128	0,128	0,138	0,133	0,148	0,142	0,128	0,141
	2004	0,016	0,010	0,013	0,008	0,012	0,010	0,011	0,010	0,016	0,012
	2005	0,000	0,000	0,001	0,001	0,000	0,000	0,001	0,001	0,000	0,000
	2006	0,162	0,163	0,155	0,142	0,147	0,171	0,158	0,168	0,175	0,157
	2007	0,094	0,084	0,081	0,086	0,099	0,101	0,093	0,085	0,075	0,099
	2008	0,163	0,157	0,146	0,158	0,166	0,166	0,161	0,156	0,166	0,159
	2009	0,080	0,073	0,072	0,074	0,090	0,079	0,075	0,068	0,083	0,089
	2010	0,226	0,187	0,209	0,206	0,218	0,210	0,213	0,212	0,209	0,234
	2011	0,449	0,438	0,436	0,437	0,461	0,440	0,456	0,439	0,448	0,437
u	2000	0,200	0,189	0,205	0,212	0,203	0,194	0,191	0,199	0,193	0,209
	2001	0,031	0,026	0,028	0,034	0,033	0,032	0,032	0,027	0,034	0,033
	2002	0,043	0,044	0,044	0,044	0,049	0,041	0,047	0,049	0,041	0,039
	2003	0,180	0,188	0,170	0,172	0,184	0,175	0,186	0,183	0,174	0,185
	2004	0,018	0,011	0,013	0,008	0,013	0,011	0,011	0,012	0,017	0,012
	2005	0,000	0,000	0,001	0,001	0,000	0,000	0,001	0,001	0,000	0,000
	2006	0,201	0,203	0,199	0,181	0,194	0,217	0,195	0,217	0,219	0,197
	2007	0,123	0,108	0,110	0,112	0,116	0,126	0,122	0,109	0,098	0,131
	2008	0,216	0,214	0,201	0,220	0,233	0,222	0,215	0,212	0,221	0,227
	2009	0,102	0,095	0,082	0,096	0,111	0,101	0,099	0,092	0,106	0,106
	2010	0,267	0,221	0,237	0,238	0,249	0,249	0,254	0,248	0,248	0,270
	2011	0,509	0,501	0,505	0,504	0,536	0,518	0,526	0,505	0,510	0,505

This table provides the consistent, lower and upper p-values from the SPA test for different average block length selections using the zero return benchmark without adjustments for transaction costs.

Table 11: Overview robustness p-values

	year / block length	1	2	3	4	5	6	7	8	9	10
c	2000	0,322	0,290	0,282	0,264	0,300	0,277	0,311	0,296	0,287	0,309
	2001	1,000	0,998	1,000	1,000	1,000	1,000	1,000	0,999	0,999	1,000
	2002	0,768	0,775	0,760	0,770	0,758	0,754	0,750	0,760	0,750	0,742
	2003	0,041	0,044	0,038	0,049	0,041	0,046	0,046	0,048	0,042	0,040
	2004	0,011	0,010	0,008	0,008	0,004	0,007	0,006	0,013	0,007	0,002
	2005	0,033	0,021	0,022	0,025	0,027	0,031	0,025	0,025	0,027	0,029
	2006	0,025	0,022	0,024	0,026	0,033	0,029	0,025	0,028	0,027	0,031
	2007	0,013	0,013	0,009	0,020	0,014	0,011	0,013	0,019	0,009	0,016
	2008	0,926	0,942	0,925	0,927	0,924	0,910	0,929	0,937	0,927	0,919
	2009	0,044	0,043	0,059	0,044	0,046	0,050	0,040	0,064	0,050	0,043
	2010	0,370	0,375	0,377	0,376	0,366	0,340	0,394	0,377	0,388	0,349
	2011	0,168	0,155	0,162	0,168	0,166	0,164	0,189	0,176	0,175	0,162
l	2000	0,309	0,282	0,273	0,250	0,289	0,263	0,297	0,281	0,272	0,298
	2001	0,958	0,960	0,962	0,951	0,957	0,951	0,951	0,966	0,956	0,962
	2002	0,475	0,487	0,484	0,493	0,476	0,447	0,456	0,486	0,453	0,443
	2003	0,041	0,044	0,038	0,049	0,041	0,046	0,046	0,048	0,042	0,040
	2004	0,010	0,010	0,008	0,008	0,004	0,007	0,006	0,013	0,007	0,002
	2005	0,018	0,018	0,015	0,016	0,019	0,018	0,016	0,017	0,014	0,014
	2006	0,025	0,022	0,024	0,026	0,033	0,029	0,024	0,028	0,027	0,031
	2007	0,013	0,013	0,009	0,020	0,014	0,011	0,013	0,019	0,009	0,016
	2008	0,746	0,761	0,751	0,741	0,739	0,731	0,747	0,764	0,764	0,744
	2009	0,042	0,042	0,058	0,042	0,045	0,049	0,039	0,062	0,048	0,042
	2010	0,330	0,335	0,332	0,329	0,329	0,309	0,365	0,333	0,351	0,327
	2011	0,168	0,153	0,162	0,166	0,165	0,164	0,187	0,176	0,175	0,161
u	2000	0,322	0,290	0,282	0,264	0,300	0,277	0,311	0,296	0,287	0,309
	2001	1,000	0,998	1,000	1,000	1,000	1,000	1,000	1,000	0,999	1,000
	2002	0,821	0,821	0,817	0,829	0,822	0,797	0,800	0,818	0,801	0,795
	2003	0,041	0,044	0,038	0,049	0,041	0,046	0,046	0,048	0,042	0,040
	2004	0,011	0,010	0,008	0,008	0,004	0,007	0,006	0,013	0,007	0,002
	2005	0,035	0,022	0,024	0,026	0,029	0,034	0,026	0,026	0,031	0,033
	2006	0,025	0,022	0,024	0,026	0,033	0,029	0,025	0,028	0,027	0,031
	2007	0,013	0,013	0,009	0,020	0,014	0,011	0,013	0,019	0,009	0,016
	2008	0,926	0,942	0,926	0,930	0,924	0,911	0,929	0,938	0,929	0,921
	2009	0,044	0,043	0,059	0,044	0,046	0,050	0,040	0,064	0,050	0,043
	2010	0,370	0,375	0,377	0,376	0,366	0,340	0,394	0,377	0,388	0,349
	2011	0,168	0,155	0,162	0,168	0,166	0,164	0,189	0,176	0,175	0,162

This table provides the consistent, lower and upper p-values from the SPA test for different average block length selections using the buy-and-hold benchmark without adjustments for transaction costs.

Table 12: Overview robustness p-values

	year / block length	1	2	3	4	5	6	7	8	9	10
c	2000	0,894	0,892	0,897	0,895	0,890	0,886	0,888	0,885	0,899	0,898
	2001	0,064	0,061	0,066	0,060	0,056	0,056	0,060	0,063	0,070	0,074
	2002	0,405	0,397	0,427	0,414	0,389	0,417	0,420	0,422	0,412	0,414
	2003	0,220	0,231	0,243	0,241	0,237	0,216	0,229	0,235	0,222	0,221
	2004	0,406	0,369	0,387	0,385	0,388	0,400	0,399	0,392	0,378	0,390
	2005	0,321	0,296	0,320	0,288	0,313	0,293	0,311	0,296	0,298	0,298
	2006	0,335	0,341	0,346	0,349	0,341	0,342	0,346	0,345	0,338	0,360
	2007	0,131	0,136	0,143	0,132	0,164	0,148	0,148	0,142	0,146	0,133
	2008	0,264	0,269	0,266	0,260	0,277	0,264	0,275	0,259	0,259	0,259
	2009	0,184	0,175	0,174	0,184	0,179	0,169	0,154	0,171	0,161	0,162
	2010	0,267	0,289	0,278	0,272	0,278	0,264	0,256	0,267	0,257	0,286
	2011	0,616	0,615	0,587	0,614	0,608	0,609	0,612	0,604	0,614	0,603
l	2000	0,764	0,751	0,752	0,751	0,758	0,757	0,754	0,755	0,756	0,770
	2001	0,028	0,030	0,034	0,033	0,027	0,023	0,031	0,028	0,039	0,041
	2002	0,240	0,227	0,240	0,242	0,218	0,237	0,234	0,232	0,244	0,234
	2003	0,158	0,164	0,168	0,171	0,156	0,141	0,150	0,156	0,149	0,152
	2004	0,229	0,210	0,213	0,216	0,228	0,216	0,222	0,222	0,212	0,225
	2005	0,205	0,188	0,191	0,161	0,186	0,171	0,178	0,173	0,172	0,182
	2006	0,220	0,222	0,228	0,224	0,220	0,225	0,219	0,233	0,219	0,238
	2007	0,096	0,099	0,108	0,093	0,121	0,113	0,108	0,104	0,102	0,096
	2008	0,164	0,179	0,167	0,173	0,190	0,170	0,187	0,178	0,170	0,167
	2009	0,144	0,137	0,139	0,142	0,137	0,135	0,122	0,135	0,120	0,129
	2010	0,215	0,218	0,228	0,216	0,216	0,209	0,199	0,205	0,212	0,223
	2011	0,487	0,465	0,444	0,486	0,471	0,469	0,459	0,464	0,475	0,470
u	2000	0,944	0,941	0,945	0,944	0,939	0,943	0,934	0,929	0,940	0,943
	2001	0,155	0,151	0,154	0,139	0,137	0,141	0,137	0,153	0,155	0,146
	2002	0,683	0,679	0,700	0,678	0,664	0,679	0,676	0,674	0,675	0,673
	2003	0,223	0,233	0,245	0,244	0,239	0,217	0,231	0,235	0,224	0,222
	2004	0,654	0,660	0,661	0,658	0,646	0,673	0,653	0,664	0,659	0,661
	2005	0,432	0,394	0,418	0,387	0,413	0,402	0,407	0,400	0,395	0,389
	2006	0,404	0,402	0,423	0,423	0,409	0,412	0,409	0,418	0,418	0,430
	2007	0,165	0,166	0,167	0,159	0,199	0,178	0,176	0,173	0,173	0,163
	2008	0,270	0,276	0,273	0,267	0,284	0,269	0,279	0,265	0,268	0,265
	2009	0,187	0,179	0,175	0,188	0,182	0,171	0,155	0,175	0,164	0,164
	2010	0,280	0,301	0,289	0,286	0,291	0,276	0,267	0,281	0,267	0,297
	2011	0,624	0,627	0,596	0,625	0,617	0,618	0,618	0,617	0,625	0,612

This table provides the consistent, lower and upper p-values from the SPA test for different average block length selections using the zero return benchmark with adjustments for transaction costs.

Table 13: Overview robustness p-values

	year / block length	1	2	3	4	5	6	7	8	9	10
c	2000	0,650	0,659	0,641	0,663	0,625	0,663	0,675	0,667	0,633	0,662
	2001	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	2002	1,000	1,000	1,000	1,000	1,000	0,999	1,000	1,000	1,000	1,000
	2003	0,054	0,063	0,046	0,052	0,043	0,056	0,050	0,047	0,048	0,055
	2004	0,146	0,138	0,119	0,128	0,117	0,139	0,113	0,134	0,106	0,124
	2005	0,651	0,655	0,663	0,653	0,681	0,676	0,656	0,677	0,670	0,639
	2006	0,063	0,056	0,053	0,053	0,047	0,053	0,055	0,049	0,051	0,048
	2007	0,014	0,014	0,014	0,023	0,023	0,012	0,011	0,018	0,022	0,024
	2008	0,945	0,928	0,941	0,964	0,930	0,937	0,935	0,953	0,940	0,938
	2009	0,059	0,082	0,077	0,065	0,071	0,064	0,072	0,068	0,076	0,078
	2010	0,373	0,370	0,388	0,397	0,373	0,363	0,374	0,356	0,406	0,389
	2011	0,183	0,210	0,200	0,198	0,219	0,201	0,202	0,203	0,213	0,209
l	2000	0,577	0,586	0,571	0,583	0,569	0,577	0,591	0,585	0,559	0,585
	2001	0,899	0,921	0,903	0,925	0,902	0,913	0,911	0,895	0,895	0,915
	2002	0,914	0,891	0,903	0,911	0,899	0,905	0,912	0,901	0,910	0,882
	2003	0,054	0,063	0,046	0,052	0,043	0,056	0,050	0,047	0,048	0,055
	2004	0,104	0,107	0,097	0,101	0,087	0,099	0,085	0,103	0,074	0,096
	2005	0,439	0,479	0,447	0,487	0,473	0,471	0,467	0,478	0,492	0,454
	2006	0,061	0,054	0,051	0,046	0,047	0,049	0,053	0,046	0,049	0,044
	2007	0,014	0,014	0,014	0,023	0,022	0,012	0,011	0,018	0,022	0,023
	2008	0,713	0,679	0,715	0,744	0,701	0,708	0,715	0,710	0,689	0,717
	2009	0,059	0,078	0,075	0,060	0,069	0,063	0,070	0,066	0,071	0,076
	2010	0,320	0,316	0,329	0,337	0,324	0,304	0,339	0,315	0,352	0,349
	2011	0,175	0,197	0,196	0,190	0,206	0,197	0,197	0,200	0,206	0,205
u	2000	0,710	0,728	0,711	0,738	0,711	0,733	0,746	0,729	0,714	0,738
	2001	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	2002	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	2003	0,054	0,063	0,046	0,052	0,043	0,056	0,050	0,047	0,048	0,055
	2004	0,181	0,166	0,153	0,164	0,146	0,167	0,153	0,165	0,138	0,156
	2005	0,708	0,710	0,727	0,703	0,739	0,717	0,714	0,730	0,731	0,698
	2006	0,064	0,060	0,055	0,055	0,048	0,055	0,056	0,049	0,052	0,048
	2007	0,014	0,015	0,014	0,023	0,024	0,013	0,012	0,018	0,022	0,025
	2008	0,947	0,934	0,945	0,966	0,943	0,940	0,948	0,957	0,947	0,946
	2009	0,059	0,082	0,077	0,065	0,071	0,064	0,072	0,068	0,076	0,078
	2010	0,376	0,373	0,391	0,399	0,382	0,368	0,379	0,361	0,412	0,391
	2011	0,183	0,210	0,200	0,198	0,219	0,201	0,202	0,203	0,213	0,209

This table provides the consistent, lower and upper p-values from the SPA test for different average block length selections using the buy-and-hold benchmark with adjustments for transaction costs.