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PRICE MOVING AVERAGE AND VOLUME

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ABSTRACT

This work tests one of the simplest and most popular trading rules, moving average, and the relationship with trading volume by utilizing the PSI 20 Index from 1992 to 2012. In the returns scope, our results provide strong support for this technical strategy. The returns obtained from this strategy are statistically higher than the simple buy-and-hold policy, and further, buy signals consistently generate higher returns than sell signals. Overall, our results show that additional returns can be obtained from a trading strategy based on this technical rule. This study also attempts to investigate the relationship between trading volume and daily stock returns. The results obtained from the regression show that both moving average signals and volume have little explanatory power on returns in the Portuguese stock market. This conclusion brings shy support to the trading efficacy that resulted from the returns analysis.

RESUMO

Este trabalho pretende testar uma das mais simples e populares ferramentas de análise técnica, as médias móveis, e a sua relação com o volume e as rendibilidades utilizando dados do índice PSI 20 desde 1992 até 2012. Os resultados sobre as rendibilidades suportam a eficácia da utilização desta estratégia mostrando que são estatisticamente superiores às da estratégia *buy-and-hold*, e ainda, que sinais de compra geram rendibilidades consistentemente superiores às que se seguem aos sinais de venda. Em suma, os resultados mostram que podem ser obtidas rendibilidades adicionais através de estratégias baseadas nas médias móveis sobre os preços. Este estudo tenta ainda investigar a relação entre volume e as rendibilidades diárias no mercado acionista português. Os resultados da regressão mostram que tanto os sinais de compra ou venda da estratégia de médias móveis como o volume têm pouco poder explicativo sobre as rendibilidades das ações. Esta conclusão parece não ser consistente com os resultados da análise sobre as rendibilidades.

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1. INTRODUCTION

For a few decades, a vast majority of traders and professionals have been using technical analysis as an accurate technique to “predict” security prices behaviour to try to outperform the market. Technical analysis is considered by many to be the most practical way to read market signals and trace price trends based on historical data. This technique uses a lot of statistical tools and chart patterns to help technical analysts, also called chartists, read the signals and form opinions about market trends. As stated by Brock et al. (1992), “these techniques for discovering hidden relations in stock returns can range from extremely simple to quite elaborate”. One of the simplest and broadly used of these is the moving average indicator. Moving average takes a significant role as it gives an important indication to traders of when and where to place an order. We take this statistic as the basis for our study.

Beside prices, another important variable in technical analysis is volume. If you are tracing investment strategies, as any active chartist, based on the technical trading rules above or any other, you should also look to volume, or liquidity, of a security or group of securities that you are following over the time. Without liquidity, technical analysis accuracy is lost and becomes the biggest flaw in predictability. Surprisingly, although a wide range of work tried to prove trading rules efficacy, especially on the last decades, little work has been done on studying the empirical effectiveness of price and volume.

If the technical trading rules, such as price moving average, prove to be correct, and investors believe they are useful, trading volume should behave accordingly, holding all other variables equal, as they would follow the trading signs from these strategies and start buying or selling any security under their scrutiny.

The aim of this work is to find a relationship between these two major variables of technical analysis and to investigate whether and how price moving average crossover strategies and volume can influence returns on the Portuguese stock market, the PSI-20 index.

We start by studying the accuracy of moving average rules compared to a simple “buy-and-hold” (unconditional) strategy by applying the methodology of Brock et al. (1992) on returns to the Portuguese stock market, particularly the stocks of the PSI 20 Index, and find empirical evidence of a statistical difference in returns following buy and sell signals. We then tested the strategy based on the price moving average rule against the simple “buy-and-hold” strategy by making an initial investment of 1€ and comparing both the price moving average (conditional) and the “buy-and-hold” (unconditional) strategies. As the former consistently allows substantially higher profits than the latter, this suggests that an active trading strategy based on simple price moving average rules allows additional returns, what seems to reject the hypothesis of market efficiency.

We also try to study the relationship with volume by studying the influence of the price moving average on the volume distribution through one nonparametric statistical test, and could not conclude that there is an overall relationship between these two variables. Finally, we try to investigate whether volume and price moving average can influence individual stock returns by regressing these variables on returns and find if there is any statistically significant correlation between the variables.

The work is structured in the next four chapters. Chapter 2 delivers an overview of previous works on the subject and offers a base for the development of this study. Chapter 3 defines the data framework and some descriptive statistics on it and presents the methodology adopted. The results of the tests run over price and volume and from the regression on the relevant variables are presented in Chapter 4. Finally, Chapter 5 summarises the conclusions of the work, points out the limitations and offers suggestions for further investigation.

2. LITERATURE REVIEW

As previously mentioned, many studies have focused on the influence of technical trading rules over returns though only a few included volume in that equation. For instance, Blume et al. (1994) prove volume is more than a simple descriptive parameter of the trading process. Their model explains how volume captures the important information contained in the quality of traders' information signals read from technical trading rules, like price moving averages. They demonstrate that conditioning on volume enables a more accurate interpretation of market information to traders.

Campbell et al. (1993) investigated the relationship between aggregate stock market trading volume and the serial correlation of daily stock returns. They study the influence of "noninformational" or "liquidity" traders on the stock prices through volume, and the role of "market makers" in accommodating their buying and selling pressures. The authors run a series of empirical experiments regressing stock prices and volume on the stock returns and find that their detrended volume series brings additional power of explanation when interacted with the regressor.

Technical analysis role in terms of influencing liquidity provision is studied by Kavajecz & Odders-White (2004). They find that the state of liquidity on trader's limit order book is related to support and resistance levels as well as moving average forecasts. Moreover, the authors conclude that support and resistance levels match peaks in depth on the limit order book and that moving average forecasts reveal information about the relative position of depth on the book.

Gervais et al. (2001) offer a perspective of the power of trading volume on the future evolution of stock prices and find that stocks with higher (lower) trading activity over a day or a week tend to experience higher (lower) returns over the following month. They state that this fact may result from the increasing visibility of a stock experiencing a shock in volume and the subsequent demand affecting its price. Their conclusions on the power of trading volume to predict future stock price movements support the argument of Blume et al. (1994) that the trading volume properties of large firms differs from those of small firms.

Although the usefulness of technical rules claimed by traders, many academics and market professionals have criticised technical analysis because admitting its application would reject the hypothesis of market efficiency where extraordinary returns are not possible considering only the available information in the market. Fama (1970) first presented this hypothesis which is broadly accepted both by academics and professionals. In an earlier work, Fama & Blume (1966) discussed a trading filter rule previously presented by Alexander (1961, 1964) and concluded that no returns from the filter technique are as large as the buy-and-hold policy.

Nonetheless, many studies have supported technical analysis, and particularly the practical application and power of some technical analysis tools. Neftci (1991) suggests that traders have been more interested in technical analysis since the crash of financial markets in late 80’s because it can better provide information to “predict” nonlinear events. To study the predictive power of technical analysis, Neftci develops formal algorithms that try to mathematically define technical trading rules and concludes moving average is the most reliable rule. In one hand, it was one of the few rules generating easy quantifying Markov times, random time periods that depend only on current information. On the other hand, the empirical tests suggested the moving average rule might capture some information to the Wiener-Kolmogorov prediction theory if the processes were considered to be nonlinear.[1]

Goldberg & Schulmeister (1989) use high frequency data from S&P and Dow Jones to test the weak efficiency form in the stock market during the 1970's and 1980's and found that this market is actually inefficient, opposing Fama & Blume (1966), as they conclude that past stock prices contain relevant information for predicting future price movements and, as cash and future markets are quite interdependent, price movements in one market are quickly transmitted to the other. Additionally, they conclude that higher frequency (hourly) data analysis has more power of explanation, and are more profitable, then daily data analysis.

Lo et al. (2000) develop algorithms to identify technical analysis patterns in NYSE/AMEX and Nasdaq stocks and run goodness-of-fit tests to try to answer the question of whether or not technical analysis is informative. They found empirical evidence of incremental information from the application of the technical patterns studied over many periods.

The study of Gençay & Stengos (1998) examines the predictability of stock returns with moving average rules and their empirical results show some nonlinear predictability in returns using the past buy and sell signals of the moving average rules. In addition, they find that past information on volume improves the forecast accuracy of current returns.

Treynor & Fergusson (1985) assume market efficiency to analyse the importance of closer past price analysis in the exploitation of unusual profits. They show the

[1] Like other well-defined techniques investigated by Neftci, the moving average rule proved to be useless in prediction if the processes under consideration were linear.

importance of value of the information, the propagation of information and the probability of calculation of market date. According to them, the use of security prices by traders is important to understand if they received the information prior to the market so they can understand how to use it in the strategy (if they can still build one).

Brown & Jennings (1989) demonstrate technical analysis is important for a trader/investor to alter the optimal policy of an individual. Adding historical prices to any individual information set, ameliorates information on the strategy building. In their paper, the market is not weak form efficient because technical analysis (the consideration of historical prices) does have value.

An interesting study presented by Brock et al. (1992) on simple technical trading rules profitability finds that returns resulting from moving average and trading range break strategies are consistently larger than the simple buy-and-hold strategy in their sample. The authors build several rules using moving average statistics on prices of Dow Jones stocks and analyse the returns on both buy and sell sides following the corresponding signals revealed by the moving average trading rules. Their results generally show that returns during buy periods are larger than returns during sell periods, and that returns during buy periods are less volatile than returns during sell periods. At last, the authors conclude that the returns obtained from these strategies are not consistent with four popular equilibrium models.

As mentioned before, volume plays a relevant role for traders in confirming any price trend showed by technical analysis signals, so it becomes important to understand the correlation between these two market variables. Literature is plenty of studies on stock market trading volume, though mostly focused on the relationship between volume and the volatility of stock returns. In contrast, there is too little study concerned with the correlation between price and trading volume, and particularly in the

Portuguese stock market. Below, we focus on this relationship in the particular case of the PSI 20 stock index.

3. DATA AND METHODOLOGY

3.1. DATA

The data series include the daily prices and volume from the constituents of the PSI 20 index, extracted from Thompson Reuters Datastream database, from 31 December 1992, the index inception date, to 28 February 2012, for a total of 5004 days, except for the case of Banco Espírito Santo (BES) where the series start on 15 July 1994 due to missing data for 43 following trading days prior to this date. Similarly to the work of Lo et al. (2000), a filter was run over the 20 stocks to exclude the ones with less than 80% of price and volume data within the sample range. This procedure allows the exclusion of delistings and stocks with little time of existence in the index. To exclude exogenous factors, the securities which have witnessed a split during this period were also removed from the analysis.

In addition, this initial sample, ranging about twenty years of data, was also divided into four subsamples of approximately five years each. This will bring additional robustness to the analysis. The partition is intended to separate the data and big events that might have influenced trades. The first five years include the beginning of an uptrend in the Portuguese economy. The second period of five years captures the filing of many information technology companies in 2000 after the so-called “dot-com bubble”. A new upturn in markets worldwide is seen in the years included in the third period. And finally, the subprime crisis leading to Lehman Brother’s fall and the actual sovereign debt issues in Europe are captured in the last five years. We call the twenty years sample as Total Sample, and the four subsamples as Sample A, B, C and D. The dates (start:end) of the subsamples are as follow: 31-12-1992:31-12-1997 (Sample A); 01-01-1998:31-12-2002 (Sample B); 01-01-2003:31-12-2007 (Sample C); 01-01-2008:28-02-2012 (Sample D).

Results for several moving average rules and the use of the entire data series of the index may help mitigate any spurious patterns in the data. Additionally, the PSI 20 includes the 20 stocks with the largest market capitalization in the Portuguese market so all the stocks are actively traded and problems with non-synchronous trading should be of little concern in the PSI 20 because we conduct the analysis for several stocks individually and for different subsamples.

Through chart observation, one can find some relation between stock price moves, or returns, and volume, as is the case of Sonae SGPS presented in Figure 1 (see Figures A.1 to A.9 in the appendix for the other stocks). However, adding the 200-day moving average indicator does not appear to bring additional explanatory power. Nevertheless, it is important to study if there is any effect in volume if applying these trading rules, as so many traders actually use them.

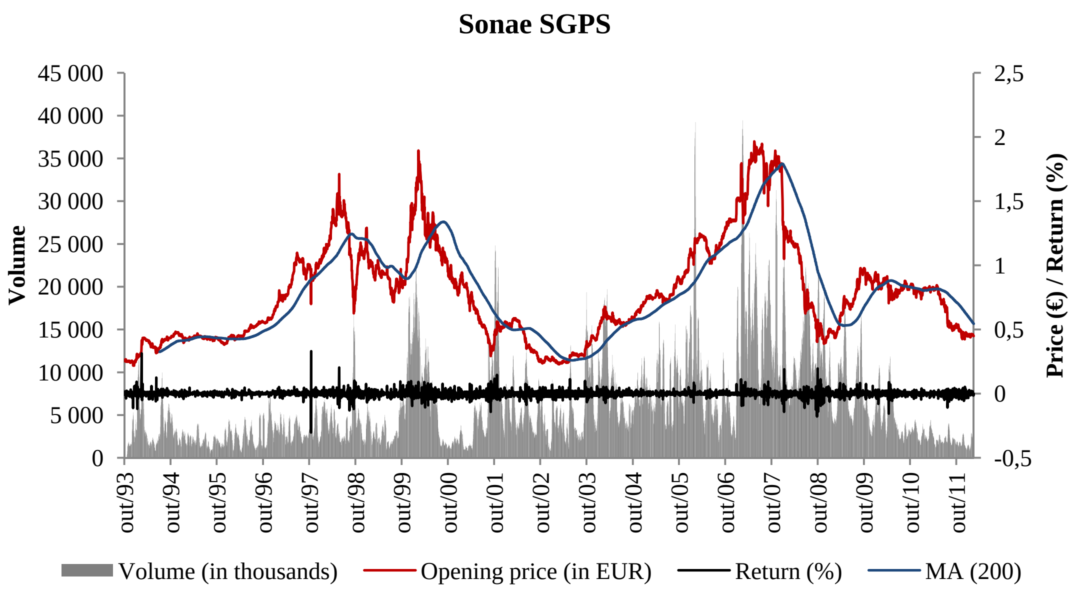

FIGURE 1: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF SONAE SGPS

The summary statistics of the daily unconditional returns and volume for the 10 stocks that survived the filtering process are presented in Table I. We will call this unconditional mean return, the “buy-and-hold” (unconditional) strategy, which can be seen in the line *Mean* of Table I. Returns are calculated as log differences of stocks prices. Volume, the number of stocks traded, is presented in thousands. Panel A shows the descriptive statistics for daily returns. Although performances can range from -0.00046 (BCP) to 0.00035 (Semapa), the overall (average) return is null. All stocks show some evidence of skewness and excess kurtosis. Volatility is higher for Sonae Indústria (Sonae Ind.) that also witnessed the second worst performance and presents the less skewed and leptokurtic distribution. The information can also be observed in the four nonoverlapping subsamples mentioned before. A few words are worth to be outlined from here. In one hand, the first subsample, Sample A, is clearly not normally distributed what might be an expected characteristic of the years corresponding to the beginning of the market in Portugal. On the other hand, the four subsamples follow what apparently look as different cycles, or trends, if we look at the returns mean, and what could be empirically observed from the previously mentioned figures shown in the appendix. Sample A data is marked by a “bullish” market, while the data in Sample B seem to suggest an inversion to a “bearish” market, and the pattern repeats in the following two samples (Samples C and D are again “bullish” and “bearish”, respectively).

In Panel B, all stocks show significant skewness and excess kurtosis, which suggests the distribution of volume is not normal. To confirm this, Kolmogorov-Smirnov statistics for each stock was computed to test the normality of the distribution. The p-value of the 5% significance level test is showed in the line labelled *K-S (p-value)*. For every stock, the null hypothesis is rejected that volume follows a normal distribution.

TABLE I: SUMMARY STATISTICS FOR DAILY RETURNS AND VOLUME

Descriptive statistics and Kolmogorov-Smirnov (K-S) test for normality of each 10 stocks resulting from the filtering process. *N* is the number of days with available price and volume data for each stock. *Mean* and *Std. dev.* represent the mean and standard deviation of price returns and volume for each stock. *Skewn.* and *Kurt.* are respectively skewness and kurtosis of price returns and volume distributions of each stock. The first five autocorrelations of each stock are given by $\rho_1,\ldots,\rho_5$. Autocorrelations for volume are measured using the differenced log volume series. *LBP stat.* refers to the Ljung-Box-Pierce statistic and it is distributed $\chi^2(5)$ under the null hypothesis of identical and independent distribution. *K-S (p-value)* shows the p-value of the hypothesis in the Kolmogorov-Smirnov test that volume is normally distributed. Panel A presents the descriptive statistics for daily returns. The information in Panel A is divided into five data samples (Total Sample and Samples A, B, C and D). The corresponding statistics for volume are shown in Panel B.

	Stocks									
Statistics	**BCP**	**BES**	**BPI**	**Cimpor**	**Mota-Engil**	**PT**	**Portucel**	**Semapa**	**Sonae Ind.**	**Sonae SGPS**
Panel A: Daily Returns										
Total Sample (31-12-1992 : 28-02-2012)										
N	4,611	4,794	4,794	4,598	4,254	4,368	4,350	4,324	5,253	4,794
Mean	-0.00046	-0.00007	-0.0002	0.00027	-0.00004	0.00012	0.00014	0.00035	-0.00023	0.00012
Std. dev.	0.0205	0.0182	0.0214	0.0168	0.0220	0.0215	0.0181	0.0188	0.0248	0.0239
Skewn.	0.204	0.362	0.493	-0.158	0.622	-0.162	-0.147	0.165	0.070	0.781
Kurt.	13.59	24.26	35.41	19.35	13.43	20.43	18.83	20.45	11.20	26.46
ρ_1	0.023	-0.001	-0.002	-0.000	-0.040	-0.010	-0.005	-0.001	0.001	-0.010
ρ_2	-0.022	-0.004	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.002	0.001
ρ_3	-0.012	0.004	-0.000	0.001	0.003	-0.001	0.000	0.000	-0.000	0.002
ρ_4	0.009	0.002	0.001	-0.000	0.011	0.001	-0.001	0.000	0.000	0.000
ρ_5	-0.007	0.000	0.000	-0.000	-0.001	-0.001	0.001	0.000	-0.000	0.001
LBP stat.	61.986	0.1556	0.0291	0.0045	72.227	0.4489	0.1069	0.0058	0.0214	0.5064
$\chi^2_{0.05}(5)$	11.07									
Sample A (31-12-1992 : 31-12-1997)										
N	1,099	1,099	1,099	903	559	673	655	629	1,305	1,099
Mean	0.0005	0.0009	0.0005	0.0008	0.0005	0.0015	0.0000	0.0020	0.0015	0.0013
Std. dev.	0.0145	0.0164	0.0204	0.0137	0.0167	0.0187	0.0197	0.0204	0.0258	0.0226
Skewn.	1.425	1.049	1.448	-0.599	-0.346	-0.509	-1.070	0.921	0.290	3.036
Kurt.	74.98	104.33	147.82	103.77	7.65	105.87	56.61	77.13	14.58	105.30
Sample B (01-01-1998 : 31-12-2002)										
N	1,304	1,304	1,304	1,304	1,304	1,304	1,304	1,304	1,304	1,304
Mean	-0.0003	0.000	-0.0002	0.0001	-0.0002	-0.0002	0.0000	-0.0002	-0.0006	-0.0011
Std. dev.	0.0186	0.0171	0.0212	0.0176	0.0235	0.0280	0.0200	0.0192	0.0205	0.0273
Skewn.	-0.011	0.241	-0.090	-0.140	1.558	-0.263	0.573	0.474	0.131	0.444
Kurt.	9.02	11.09	10.40	10.14	19.03	7.09	5.62	4.06	9.40	5.56
Sample C (01-01-2003 : 31-12-2007)										
N	1,304	1,304	1,304	1,304	1,304	1,304	1,304	1,304	1,304	1,304
Mean	0.0003	0.0003	0.0007	0.0005	0.0010	0.0004	0.0005	0.0007	0.0004	0.0015
Std. dev.	0.0161	0.0075	0.0132	0.0109	0.0170	0.0126	0.0137	0.0151	0.0206	0.0181
Skewn.	0.349	0.538	3.273	-0.086	0.027	3.033	0.337	-0.493	0.237	0.398
Kurt.	0.21	11.38	49.87	8.58	8.70	48.34	15.68	12.72	18.28	6.87
Sample D (01-01-2008 : 28-02-2012)										
N	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086
Mean	-0.0025	-0.0016	-0.0020	-0.0002	-0.0014	-0.0007	-0.0001	-0.0004	-0.0021	-0.0013
Std. dev.	0.0302	0.0278	0.0292	0.0230	0.0271	0.0225	0.0193	0.0211	0.0310	0.0267
Skewn.	0.214	0.278	0.163	-0.022	0.205	-0.3354	-0.672	-0.208	0.105	0.045
Kurt.	4.903	3.612	3.007	7.079	6.967	8.403	8.338	4.328	5.405	10.878
Panel B: Daily Volume										
Total Sample (31-12-1992 : 28-02-2012)										
N	4,611	4,794	4,794	4,598	4,254	4,368	4,350	4,324	5,253	4,794
Mean	12,821.08	1,067.45	1,277.82	994.01	262.86	4,488.09	855.10	156.18	161.92	6,230.21
Std. dev.	22,532.15	1,740.66	1,842.55	2,324.15	472.91	4,408.83	2,030.84	316.49	342.17	7,529.01
Skewn.	6.88	8.97	8.44	15.12	14.51	7.42	18.42	15.17	4.26	4.22
Kurt.	90.49	210.48	124.33	350.42	464.73	121.48	600.67	405.66	25.95	42.32
K-S (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ρ_1	-0.393	-0.384	-0.407	-0.393	-0.416	-0.341	-0.392	-0.405	-0.408	-0.391
ρ_2	-0.012	-0.057	-0.013	-0.030	-0.043	-0.095	-0.046	-0.016	-0.045	-0.067
ρ_3	-0.083	-0.052	-0.063	-0.068	0.011	-0.044	-0.018	-0.088	0.003	0.003
ρ_4	-0.028	0.002	-0.013	-0.005	-0.051	-0.030	-0.025	0.021	-0.033	-0.052
ρ_5	0.032	0.017	0.036	0.014	0.005	0.068	0.004	0.030	-0.013	0.076
LBP stat.	784.57	734.89	822.19	735.45	757.09	578.82	680.82	749.58	894.28	794.68
$\chi^2_{0.05}(5)$	11.07									

Blume et al. (1994) have previously stated that the volume statistic is not normally distributed. Sonae Indústria is the stock with the highest number of observations in the raw data as well as the less skewed and leptokurtic volume distribution.

From the observation of the autocorrelation list, one can conclude that returns have no significant autocorrelations. On the other hand, the volume series (we use the differenced log volumes to obtain a stationary series) show significant autocorrelations in the first lag and that all stocks give strong rejection of the null hypothesis of identical and independent observations.

The analysis of Panel B data, suggests the use of nonparametric tests where no distribution is assumed (distribution-free) because the corresponding parametric tests are not applicable in this case as the volume distribution is clearly not normal. In particular, the Mann-Whitney statistic will be used to test the hypothesis that the medians of buys and sells are different. In this statistic, equal distributions between two independent populations are assumed, no matter the distribution format. To test for equal distributions between the two populations, the equivalent nonparametric Levene's test is used. The formulation of this statistic is explained below. This will bring robustness of results for statistical inference.

3.2. METHODOLOGY

Stock prices show a very volatile movement over time what can make it difficult for traders to identify its overall trend. The price moving average is one of the most widely and simplest technical tools applied by chartists to mitigate this. A price moving average is the average price of the stock over a set amount of time. For instance, an n--period moving average is computed by calculating the average of the n most recent days. This average is recalculated daily by dropping the oldest data and adding the most recent, so the average moves with its data but does not fluctuate as much. A typical moving average rule on prices can be written as:

$$m_t = \left(\frac{1}{n}\right)\sum_{i=0}^{n-1} p_{t-i} \qquad \text{where } p_{t-i} \text{ is the stock price for day } t\text{-}i \qquad (1)$$

Once the day-to-day fluctuations are removed and a trend can be outlined, the rule can be used to help determine an uptrend or a downtrend if both price and a relevant moving average are used. Another method of determining momentum is to look at the cross of a pair of (unweighted) moving averages: a short period average and a long period average. This rule is an important method to identify buy and sell signals. When the short period average crosses the long period average from below (above), commonly called a golden (death) cross, the trend is up and it suggests a buy (sell) signal. In other words, the trading rule is to hold a long position when the difference between the short-term and the long-term moving average is positive, and to hold a short position otherwise.

To implement this strategies, a few of the most popular moving averages were built over the price series for each stock, with 2, 5, 50, 150 and 200 days lag, to build the moving average rules tested in the work of Brock et al. (1992), without the 1% bandwidth because there were no evidence of additional effectiveness in introducing the band. The rules differ by the length of the short and the long periods. The notation used is 1-50, 1-150, 5-150, 1-200 and 2-200, for the five rules constructed, where the first digit is the number of days of the short period and the latter ones are the number of days for the long period. Brock et al. (1992) state that the 1-200 moving average rule is the most broadly used, where the moving average pair 1 day and 200 days, for the short period and the long period, respectively, is used to identify signals.

The trading rule used when considering returns is as follows: if the short-term moving average, computed over the price series, is above the long-term one, a buy signal is generated and is identified as “1”, and “-1” otherwise. From this rule, two groups are created, whether they are *buys* or *sells*, depending on the relative position of the moving averages.

In order to compare this five moving average strategies to the “buy-and-hold” (unconditional) strategy, we first run *t*-tests for the difference of the mean buy and mean sell returns from the “buy-and-hold” (unconditional) daily mean return (presented in Table I) and buy-sell from zero, for each stock. We then apply the strategy attempting to replicate a real investment according to both the “buy-and-hold” strategy and the trading rule described above. The former consists of buying the stock in the first trading day and holding it until the last trading day, then selling it. The latter assumes holding a long position as long as a buy signal is returned while in the case of a sell signal the shares are sold out and the trader waits until a new buy signal is received (we have not considered the investment in the risk-free asset or transaction costs). The profit analysis takes an initial investment of 1 € for both strategies, to simplify, and applies to the whole data sample. This approach intends to confirm whether the conclusions of the previous statistical tests are robust or not.

The trading rule used to study volume is quite similar to the one used in returns: each day where the short period moving average crosses the long period moving average from below (above), is identified with “1” (“-1”). The main difference of the trading rule of volume relies on the number of signals reported as in this case only the trading volume in each day reporting a signal is listed in one of the two groups, whether they are buys or sells, instead of a continuous series. To clarify, the moving average rules used for volume analysis are still calculated over the prices series, as well as the ones used in returns.

As presented in the previous section, the analysis of the raw data in Table I, suggested the use of nonparametric tests because the corresponding parametric tests are not applicable in this case as the volume distribution is not normal. The Mann-Whitney U test[2] is used to investigate whether median volume of buys is statistically higher (lower) than median volume of sells. The equivalent nonparametric Levene's test[3] for equal variances, without assuming that groups are normally distributed is used to test homogeneity of variances between the ranked groups used in the Mann-Whitney U test and it brings additional robustness by confirming (or not) the groups have equal distributions. This conclusion is important to assess the validity of the first assumption of equal distributions between the two groups investigated in the Mann-Whitney U test. This statistic is computed as a one-way ANOVA over the absolute deviation of the population rank, independently of the groups, and the mean of the ranked population separated by the groups, according to the following expression:

$$Abs_i\left[rank_i - mean\left(rank_{ij}\right)\right], \quad i = 1, 2, \dots, N \text{ and } j = buy, sell \qquad (2)$$

Finally, we entail an analysis of the correlation between prices (returns) and volume, using price moving average signals from one trading strategy as well as volume and one-day-lag volume interacted with one-day-lag returns, following the approach by Campbell et al. (1993), using the regression below:

$$return_t = \alpha + \beta\ signal_t + (\gamma_1 vol_t + \gamma_2 vol_{t-1})return_{t-1} + \varepsilon_t \qquad (1)$$

2 Mann and Whitney (1947).

3 See Chapters 10 and 12 of Ramachandran et al. (2009) for information about ANOVA (Analysis of Variance) and nonparametric tests, respectively. Also note that, as stated by the authors, the Mann--Whitney U test is equivalent to the Wilcoxon rank sum test.

The signals resulting from the daily moving average rule on prices are included as an independent variable and take the values "1" or "0", whether they are buys or sells, respectively. This methodology tries to replicate the strategy where we buy once a buy signal is generated and hold a long position until a sell signal is shown, then sell when a sell signal is presented and stay out of the market until a new buy signal is returned. Moreover, we need to work with stationary series so we use the first difference log volume series, in accordance to the same authors. Finally, we also need a measure of stock return volatility. To accomplish that, we compare the results using the generalized autoregressive conditional heteroskedasticity (GARCH(1,1)) and the exponential generalized autoregressive conditional heteroskedasticity (EGARCH(1,1)) and select the one that best fits the model, according to the minimum method selection criterion. The reason to consider an EGARCH along with the standard GARCH model relies on the fact that the former allows negative returns to increase volatility more than the positive ones.

4. RESULTS ANALYSIS

4.1. THE PRICE MOVING AVERAGE STRATEGY

The trading rule behind this strategy is that the trader buys when the short moving average crosses the long moving average from below and holds the position until the short moving average crosses the long one from above. After receiving this signal, the trader steps out of the market or hold a short position. A graphical example of the 1-200 moving average strategy of Sonae Indústria is presented in Figure 2 below to help the perception by the reader. The *buys* are signalled in the solid dark area while *sell* signals occur in the light red area.

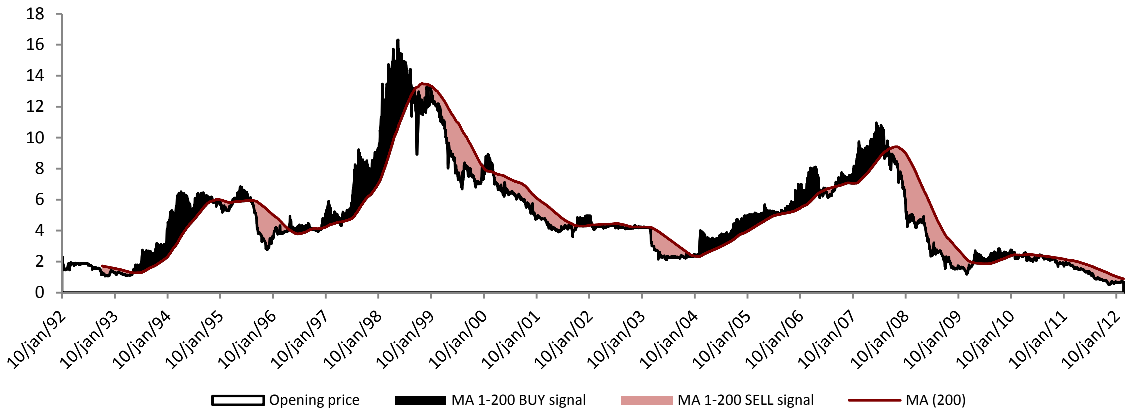

FIGURE 2: THE 1-200 MOVING AVERAGE STRATEGY EXAMPLE FOR SONAE INDÚSTRIA

Table II reports the daily returns of both buy and sell periods replicated by the strategy above for each pair of moving averages (named "MA strategy" hereafter), and the corresponding p-values resulting from the *t*-tests for the difference of the mean buy and mean sell returns from the "buy-and-hold" (unconditional) daily mean return (presented in Table I) and buy-sell from zero[4], for each stock. The number of signals generated by each strategy, whether they are buys or sells, is showed in column N total. N buys and N sells state respectively the number of buy and sell signals resulting from the moving average strategies listed in the MA strategy column for each stock.

[4] The *t*-statistics for the buys (sells) are the ones used by Brock et al. (1992),

$$\frac{\mu_r - \mu}{\sqrt[2]{\left(\frac{\sigma^2}{N} + \frac{\sigma^2}{N_r}\right)}}, \qquad (3)$$

where μ_r and N_r are the mean buy (sell) return and number of buy (sell) signals, and μ and N are the unconditional mean return and number of observations. σ^2 is the estimated variance for the whole sample. In the case of buy-sell, the *t*-statistic is,

$$\frac{\mu_B - \mu_S}{\sqrt[2]{\left(\frac{\sigma^2}{N_B} + \frac{\sigma^2}{N_S}\right)}}, \qquad (4)$$

where μ_B and N_B are respectively the mean return and number of buy signals, and μ_S and N_S are the mean return and the number of sell signals.

The results in Table II show that for all stocks buy returns (presented in column 5) are, on average, statistically higher than the “buy-and-hold” (unconditional) one-day return. Considering the results individually, the conclusion holds for almost all the strategies, except for a few cases. Additionally, the differences between the mean buy and mean sell returns listed in the last column show that they are all positive and the *t*-tests for these differences are highly statistically significant, rejecting the null hypothesis of equality of means at the 5% level, except for two cases, Portugal Telecom and Portucel, where the differences from mean buy and mean sell returns for the 5-150 moving average strategy are not statistically different from zero. Not surprisingly, the one sample *t*-tests for the buys in the cases mentioned above do not reject also the null hypothesis that the mean buy return is equal to the “buy-and-hold” (unconditional) one-day mean return. It is important to note also that in 5 out of 10 stocks, the p-values of the *t*-tests of the 5-150 moving average strategy show that the difference between mean buys and (or) mean sells are not statistically significant from the simple “buy-and-hold” (unconditional) one-day mean return presented in Table I, suggesting this moving average strategy does not appear to be a good trading strategy as no additional return can be obtained.

TABLE II: TEST RESULTS ON RETURNS FOR THE MOVING AVERAGE RULES

Results for daily data from inception date in the stock market to 28 February 2012, for each stock. Rules are shown according to the notation “short-long” to define the moving average (MA) strategy with a short period and a long period moving average, respectively. *N buys* and *N sells* are the number of buy and sell signals generated during the period. In *Buy* and *Sell* columns, each cell contains the respective mean return per strategy for each stock and, in brackets, the corresponding p-value of the *t*-test for the difference of the mean buy and mean sell from the “buy-and-hold” (unconditional) one-day mean presented in Table I. *Buy-Sell* shows the difference between columns *Buy* and *Sell* and the p-value of the *t*-test for the equality of means below, testing the difference (buy-sell) from zero. Numbers marked with an asterisk are statistically significant at the 5% level for a two-tailed test.

Stock	MA strategy	N buys	N sells	Buy	Sell	Buy-Sell
BCP	1-50	2,230	2,513	0.00301 (0.000)*	-0.00357 (0.000)*	0.00658 (0.000)*
	1-150	2,039	2,604	0.00185 (0.000)*	-0.00231 (0.000)*	0.00416 (0.000)*
	5-150	2,044	2,599	0.00067 (0.002)*	-0.00139 (0.043)*	0.00206 (0.001)*
	1-200	1,964	2,631	0.00162 (0.000)*	-0.00202 (0.001)*	0.00364 (0.000)*
	2-200	1,959	2,636	0.00102 (0.000)*	-0.00157 (0.015)*	0.00259 (0.000)*
	Average	-	-	0,00163	-0,00217	0,00381

BES	1-50	2,484	2,261	0.00267 (0.000)*	-0.00009 (0.936)	0.00276 (0.000)*
	1-150	2,378	2,334	0.00118 (0.000)*	-0.00171 (0.000)*	0.00289 (0.000)*
	5-150	2,298	2,347	0.00070 (0.005)*	-0.00090 (0.074)	0.00160 (0.003)*
	1-200	2,301	2,294	0,00136 (0.000)*	-0.00159 (0.001)*	0.00295 (0.000)*
	2-200	2,293	2,302	0.00093 (0.000)*	-0.00114 (0.022)*	0.00207 (0.000)*
	Average	-	-	0,00137	-0,00109	0,00245
BPI	1-50	2,458	2,287	0.00311 (0.000)*	-0.00379 (0.000)*	0.00690 (0.000)*
	1-150	2,486	2,334	0.00126 (0.000)*	-0.00233 (0.000)*	0.00359 (0.000)*
	5-150	2,312	2,333	0.00091 (0.004)*	-0.00129 (0.030)*	0.00220 (0.001)*
	1-200	2,307	2,288	0.00171 (0.000)*	-0.00201 (0.001)*	0.00372 (0.000)*
	2-200	2,301	2,293	0.00142 (0.000)*	-0.00143 (0.016)*	0.00285 (0.000)*
	Average	-	-	0,00168	-0,00217	0,00385
Cimpor	1-50	2,593	1,955	0.00262 (0.000)*	-0.00283 (0.000)*	0.00515 (0.000)*
	1-150	2,728	1,721	0.00165 (0.000)*	-0.00189 (0.000)*	0.00354 (0.000)*
	5-150	2,729	1,719	0.00073 (0.100)	-0.00043 (0.157)	0.00116 (0.028)*
	1-200	2,711	1,688	0.00158 (0.000)*	-0.00182 (0.000)*	0.00340 (0.000)*
	2-200	2,710	1,689	0.00092 (0.022)*	-0.00075 (0.040)*	0.00167 (0.002)*
	Average	-	-	0,00150	-0,00154	0,00298
Mota-Engil	1-50	2,074	2,130	0.00379 (0.000)*	-0.00376 (0.000)*	0.00755 (0.000)*
	1-150	2,275	1,829	0.00207 (0.000)*	-0.00264 (0.000)*	0.00471 (0.000)*
	5-150	2,290	1,814	0.00120 (0.002)*	-0.00158 (0.012)*	0.00278 (0.000)*
	1-200	2,237	1,817	0.00187 (0.000)*	-0.00236 (0.000)*	0.00423 (0.000)*
	2-200	2,229	1,826	0.00132 (0.001)*	-0.00167 (0.007)*	0.00299 (0.000)*
	Average	-	-	0,00205	-0,00240	0,00445
PT	1-50	2,325	1,994	0.00328 (0.000)*	-0.00354 (0.000)*	0.00682 (0.000)*
	1-150	2,438	1,781	0.00232 (0.000)*	-0.00284 (0.000)*	0.00516 (0.000)*
	5-150	2,417	1,802	0.00037 (0.628)	-0.00016 (0.562)	0.00053 (0.436)
	1-200	2,423	1,746	0.00195 (0.000)*	-0.00250 (0.000)*	0.00445 (0.000)*
	2-200	2,436	1,733	0.00085 (0.066)	-0.00099 (0.067)	0.00184 (0.008)*
	Average	-	-	0,00175	-0,00201	0,00376
Portucel	1-50	2,323	1,976	0.00279 (0.000)*	-0.00297 (0.000)*	0.00576 (0.000)*
	1-150	2,480	1,721	0.00172 (0.000)*	-0.00201 (0.000)*	0.00373 (0.000)*
	5-150	2,481	1,720	0.00063 (0.124)	-0.00046 (0.241)*	0.00109 (0.057)
	1-200	2,430	1,867	0.00153 (0.000)*	-0.00091 (0.033)*	0.00244 (0.000)*
	2-200	2,429	1,721	0.00079 (0.038)*	-0.00065 (0.122)	0.00144 (0.011)*
	Average	-	-	0,00149	-0,00140	0,00289
Semapa	1-50	2,425	1,848	0.00327 (0.000)*	-0.00354 (0.000)*	0.00681 (0.000)*
	1-150	2,527	1,648	0.00194 (0.000)*	-0.00220 (0.000)*	0.00414 (0.000)*
	5-150	2,519	1,656	0.00094 (0.067)	-0.00066 (0.066)	0.00160 (0.007)*
	1-200	2,600	1,525	0.00169 (0.000)*	-0.00208 (0.000)*	0.00377 (0.000)*
	2-200	2,591	1,534	0.00113 (0.014)*	-0.00111 (0.013)*	0.00224 (0.000)*
	Average	-	-	0,00179	-0,00192	0,00371
Sonae Ind.	1-50	2,425	2,778	0.00424 (0.000)*	-0.00407 (0.000)*	0.00831 (0.000)*
	1-150	2,304	2,800	0.00281 (0.000)*	-0.00263 (0.000)*	0.00544 (0.000)*
	5-150	2,322	2,782	0.00170 (0.000)*	-0.00174 (0.002)*	0.00344 (0.000)*

	1-200	2,306	2,748	0.00227 (0.000)*	-0.00213 (0.000)*	0.00440 (0.000)*
	2-200	2,295	2,759	0.00178 (0.000)*	-0.00171 (0.002)*	0.00349 (0.000)*
	Average	-	-	0,00256	-0,00246	0,00502
Sonae SGPS	1-50	2,546	2,199	0.00358 (0.000)*	-0.00387 (0.000)*	0.00745 (0.000)*
	1-150	2,489	2,156	0.00257 (0.000)*	-0.00288 (0.000)*	0.00545 (0.000)*
	5-150	2,464	2,181	0.00120 (0.004)*	-0.00127 (0.019)*	0.00247 (0.000)*
	1-200	2,665	1,930	0.00200 (0.000)*	-0.00265 (0.000)*	0.00465 (0.000)*
	2-200	2,665	1,930	0.00144 (0.000)*	-0.00187 (0.002)*	0.00331 (0.000)*
	Average	-	-	0,00216	-0,00251	0,00467

The sells are all negative and fall below the “buy-and-hold” (unconditional) one-day mean return, except for a few cases where the mean sell returns are not statistically different from the unconditional mean return, assuming a 5% level two-tailed test. In the case of Banco Espírito Santo (BES), although the number of sell signals resulted from the 1-50 moving average strategy was almost twice the number of buys, the mean sell return is not statistically different from the unconditional mean of -0.007 per cent (see Table I), as the p-value is very high.

A separate analysis was conducted for each of the subsamples (see Table A.1 to A.4 of the appendix) and the conclusions are quite similar to the total sample ones. Please note that for Sample A, showing the most volatile distribution of returns due to including the inception and less liquid market period, the test results do not allow a conclusion on the strategies efficiency. All the other subsamples suggest consistent conclusions with the total sample results where nearly all stocks show that using the 5-150 moving average strategy does not allow a higher return than the unconditional strategy. This is also true for the 2-200 moving average rule, where at least 9 out of 10 stocks have no statistical difference between conditional and unconditional returns. In addition, the difference between buy and sell average returns are all positive (except for two cases in the 5-150 moving average rule of Portugal Telecom stock) and statistically different from zero.

4.2. THE STRATEGY IN PRACTICE

The trading accuracy of these moving average strategies can be better understood when comparing profits between these and the simple buy-and-hold strategy. While the former explore the strategy where we buy shares upon a buy signal and sell them upon a sell signal, the latter consists in buying shares in the first day the share went in the market and sell them in the last trading day of the sample. Table III presents the results of the comparison between the strategies for all ten stocks. Each cell contains two levels of information: first, the final value of the 1 € invested, and second, the annual return correspondent to the profit or loss over the period. Panel A shows the results for the simple buy-and-hold strategy. The profits for the five moving average strategies studied are presented in Panel B.

TABLE III: COMPARISON BETWEEN BUY-AND-HOLD AND MOVING AVERAGE STRATEGIES

Final value of the initial investment of 1 € and annual return correspondent to the profit or loss over the period, in brackets below, for every stock. Column *Strategy* defines the strategy adopted for each line of results, where *BaH* corresponds to the buy-and-hold strategy presented in Panel A. The results for the moving average strategies are presented in Panel B. Buy-and-hold explores the following strategy: we buy in the first day the stock went in the market and sell in the last trading day of the sample. Moving average strategies follows the rule: (1) buy shares upon a buy signal and hold a long position as long as a buy signal is returned and (2) sell upon a sell signal and wait (no investment in the risk-free asset or transaction costs) until a new buy signal is received.

	Stocks									
Strategy	**BCP**	**BES**	**BPI**	**Cimpor**	**Mota-Engil**	**PT**	**Portucel**	**Semapa**	**Sonae Ind.**	**Sonae SGPS**
Panel A: Buy-and-hold strategy										
BaH	1.56 € (4.21%)	0.67 € (-2.49%)	0.04 € (-7.20%)	2.23 € (9.61%)	0.84 € (-1.35%)	1.51 € (4.16%)	1.61 € (5.05%)	2.53 € (12.70%)	0.00 € (-8.22%)	1.56 € (4.21%)
Panel B: Moving Average strategy										
1-50	7.69 € (50.26%)	7.62 € (49.74%)	8.64 € (57.41%)	8.79 € (60.96%)	9.85 € (74.91%)	9.62 € (71.07%)	8.47 € (61.80%)	9.92 € (74.29%)	10.27 € (63.51%)	10.11 € (68.42%)
1-150	4.77 € (28.33%)	4.47 € (26.05%)	5.53 € (34.00%)	6.51 € (43.12%)	6.72 € (48.39%)	7.65 € (54.84%)	6.25 € (43.48%)	6.90 € (49.14%)	6.69 € (38.99%)	7.40 € (48.08%)
5-150	2.37 € (10.29%)	2.60 € (11.98%)	3.11 € (15.86%)	3.99 € (23.40%)	4.74 € (31.67%)	2.89 € (15.54%)	3.57 € (21.27%)	4.37 € (28.02%)	4.23 € (22.12%)	3.96 € (22.19%)
1-200	4.17 € (23.84%)	4.12 € (23.46%)	4.95 € (29.66%)	6.30 € (41.47%)	6.18 € (43.80%)	6.72 € (47.15%)	5.71 € (38.99%)	6.40 € (44.94%)	5.55 € (31.21%)	6.33 € (40.02%)
2-200	2.99 € (14.96%)	3.12 € (15.92%)	3.63 € (19.72%)	4.49 € (27.33%)	4.95 € (33.44%)	4.06 € (25.26%)	3.92 € (24.18%)	4.92 € (32.65%)	4.40 € (23.28%)	4.84 € (28.81%)

The results in Table III are striking. The profit gained in any moving average strategy is very much higher than in the buy-and-hold strategy. In fact, the latter experiences a loss in some of the stocks. These results seem to suggest that additional profits are able to get if we follow a technical rule such as the one behind the moving average strategies studied. Once again, in the results for Sonae Indústria lies a particular case as the stock performance forces the trader, in the case of the buy-and-hold strategy, to completely lose his investment even before reaching the last trading day in the sample. However, if we consider the 1-50 moving average strategy for this same stock, the highest profit is observed, with the trader who invested 1 € in the first day that the stock came into the market ending up with a 10.27 € profit, before transaction costs, which corresponds to a 63.51% annual rate. Overall, the results range from 0.00 € (buy-and-hold strategy - Sonae Indústria) to 10.27 € (1-50 moving average strategy - Sonae Indústria).

4.3. THE CASE OF VOLUME

After analysing the results of the *t*-tests on daily returns, it is interesting to look at the behaviour on volume to understand if there is any reaction to the buy and sell signals of the moving average strategy on prices. In particular, we are interested to study if trading volume is higher on buy periods (after a buy signal) than on sell periods (after a sell signal).

Results from the trading strategies based on the moving average rules for the full sample are presented in Table IV. The medians of the filtered volume series for the buys and sells are shown in columns six and seven. As said before, we had to use nonparametric tests because the corresponding parametric tests are not applicable in this case as the volume distribution is not normal. The Mann-Whitney U and the equivalent nonparametric Levene's tests presented in Chapter 3 are used in the hypothesis testing. The Mann-Whitney U test is displayed in the eighth column in Table IV for each moving average strategy, returning the statistic and the one-tailed p-value (exact significance) in brackets below. The last column shows the results from the equivalent nonparametric Levene's test for equal variances (ANOVA), without assuming that groups are normally distributed. The F-statistic of the one-way ANOVA and the p-value (in brackets) are displayed in the last column of Table III.

The results are consistent with the results presented in Table II. The median volumes of buys statistically different from the median volumes of sells result from moving average strategies where the mean buy returns are statistically different from the mean sell returns. Nevertheless, the results are not quite revealing of a general statistical difference between buy and sell group volumes. This may happen because the Portuguese stock market has still received little attention and study, rather than the Dow Jones or Nasdaq indices in the United States. However, there are some quite interesting results to point out as they may support some of Brock et al. (1992) conclusions. If we look at the Mann-Whitney U test column, even though in the majority of the strategies the null hypothesis cannot be rejected, a few strategies have resulted in a statistical difference between the medians of both groups. If we look at the p-values of some strategies (asterisk marks they are statistically significant) we can say, because we have reasons to believe in that, the median buy volume in a given moving average strategy is statistically higher (lower) than the median sell volume, based on the Mann-Whitney U test. The equivalent nonparametric Levene's test assesses the robustness of the Mann-Whitney U results by testing the homogeneity of variances between the groups i.e. if both groups have the same distribution. The null hypothesis in the equivalent nonparametric Levene's test is rejected in only two of the fifty statistical tests in Table II (and only marginally significant in a third one), with p-values below a 5% significance level, which supports the statistical inference power of the previous test.

The 1-200 and 2-200 moving average strategies of BCP data show a significant difference between buy and sell volumes. Particularly in these two cases, the one-tailed p-value is very low which allows us to reject the null hypothesis. In fact, the median sell volume is statistically higher than the median buy volume, in the case of BCP. Only in BCP we can conclude that the mean volume is higher in a bearish market than in a bullish one. For all the other stocks where the differences are statistically different, the results show that the mean volume is higher in an up-trended market (buys) than in a downtrend (sells). In the 1-50 strategy, the results for BES and BPI are only marginally statistical significant, though for Semapa and Sonae Indústria the median difference is highly significant and we may say the median buy volume is statistically higher than the median sell volume in these four stocks. The previous conclusion stands even though the equivalent nonparametric Levene's test for Semapa being only marginally significant what may decrease the supporting strength to the Mann-Whitney U test in this case. Mota-Engil is the only stock where the results on volumes are fully consistent with Brock et al. (1992) conclusions on returns: higher median and more volatile volume in buys than in sells, if we look at the 2-200 moving average strategy test. Another important fact to state is that there is only statistical evidence of different behaviour in volume in three strategies: 1-50, 1-200 and 2-200. These may actually be the strategies traders are using to trace price trends and identify momentum in Portuguese stocks in the PSI 20. The 1-200 moving average strategy was actually what the previous authors said to be the most popular trading rule amongst practitioners.

TABLE IV: RESULTS OF NONPARAMETRIC TESTS OVER VOLUME DISTRIBUTION

Results for daily volume data from inception date in the stock market to 28 February 2012, for each stock. Volume is given by the number of shares traded. Rules are shown according to the notation "short-long" to define the moving average (MA) strategy with a short period and a long period moving average, respectively. The number of signals generated over the entire sample is shown in column *N* total. N *buys* and *N sells* are the number of buy and sell signals generated during the period. *Median (buys)* and *Median (sells)* represent the median of each stock Volume distribution. *Mann-Whitney* and *Nonparametric Levene's test* columns contain, at a first level, the *t*-statistics of the Mann-Whitney U test and the equivalent nonparametric Levene's test for the equality of means, and the p-value of the previous *t*-statistics in brackets below. Numbers in the Mann-Whitney U (nonparametric Levene's) test column marked with one (two) asterisk(s) are statistically significant, or marginally, at the 5% level for a 1-tailed test.

Stock	MA strategy	N total	N buys	N sells	Median (buys)	Median (sells)	Mann-Whitney	Nonparametric Levene's test
BCP	1-50	158	78	80	4 545,05	4 411,80	3 063 (0,422)	0,456 (0,500)**
	1-150	69	33	36	4 328,80	6 291,45	549 (0,298)	0,065 (0,800)**
	5-150	46	23	23	5 905,80	8 117	246 (0,348)	0,263 (0,610)**

	1-200	71	38	33	2 909,05	8 165,25	446 (0,018)*	0,097 (0,756)**
	2-200	64	34	30	3 107,85	9 527,05	363 (0,024)*	0,146 (0,704)**
BES	1-50	163	88	75	631,50	366,20	2 816 (0,054)*	0,875 (0,351)**
	1-150	74	41	33	484,10	753,30	579,5 (0,147)	2,319 (0,132)**
	5-150	54	28	26	461,80	790,55	335 (0,312)	0,188 (0,667)**
	1-200	59	29	30	371,60	359,50	417 (0,396)	2,116 (0,151)**
	2-200	49	24	25	368,80	330,60	284 (0,379)	1,881 (0,177)**
BPI	1-50	165	77	88	961,70	831,70	2 903 (0,057)*	0,005 (0,945)**
	1-150	73	36	37	1 184,20	919,10	624 (0,323)	0,051 (0,822)**
	5-150	48	22	26	1 590,50	879,95	226 (0,110)	0,094 (0,761)**
	1-200	58	30	28	1 241,20	1 146,60	352 (0,148)	0,010 (0,919)**
	2-200	47	27	20	974,70	923	252 (0,355)	0,983 (0,327)**
Cimpor	1-50	206	104	102	463,15	370,10	4 667,5 (0,069)	0,072 (0,789)**
	1-150	101	52	49	497,85	426,70	1 249 (0,434)	0,071 (0,790)**
	5-150	57	29	28	353,30	373,45	392 (0,415)	0,010 (0,922)**
	1-200	83	47	36	424,40	381,35	723,5 (0,131)	2,011 (0,160)**
	2-200	71	38	33	328,25	308,90	576 (0,281)	2,239 (0,139)**
Mota-Engil	1-50	146	86	60	150,05	114,95	2 467 (0,327)	9,869 (0,002)
	1-150	63	29	34	33,70	90,65	458 (0,317)	5,929 (0,018)
	5-150	38	19	19	42,00	39,10	169 (0,373)	0,336 (0,566)**
	1-200	51	26	25	77,85	40,30	254 (0,092)	1,889 (0,176)**
	2-200	43	17	26	160,60	27,40	152,5 (0,045)*	0,164 (0,687)**
PT	1-50	161	86	75	4 896,40	4 936	2 994 (0,218)	0,774 (0,380)**
	1-150	97	42	55	4 990,65	5 818,80	1 127 (0,421)	0,13 (0,719)**
	5-150	60	27	33	5 415,90	6 184,40	420 (0,356)	0,163 (0,688)**
	1-200	85	36	49	5 702,45	5 579,20	879 (0,4919	1,227 (0,271)**
	2-200	68	30	38	5 898,45	5 634,55	544 (0,377)	0,243 (0,623)**
Portucel	1-50	148	78	70	406,85	436	2 586 (0,291)	0,647 (0,423)**
	1-150	69	43	26	649,10	399,95	473 (0,146)	2,116 (0,150)**
	5-150	47	24	23	694,05	408,10	222 (0,129)	0,009 (0,925)**
	1-200	61	35	26	550,30	403,55	406 (0,241)	0,143 (0,707)**
	2-200	50	25	25	567,70	535	300 (0,409)	0,094 (0,760)**
Semapa	1-50	166	86	80	105,10	73,30	2 898,5 (0,040)*	3,673 (0,057)
	1-150	69	36	33	67,95	94,50	529 (0,220)	0,639 (0,427)**
	5-150	50	27	23	115	166	297 (0,399)	2,471 (0,123)**
	1-200	51	25	26	142,60	71,90	240 (0,056)*	0,215 (0,645)**
	2-200	47	20	27	109,40	76	231,5 (0,207)	2,310 (0,136)**
Sonae Ind.	1-50	162	81	81	69,20	29,40	2 694 (0,025)*	0,037 (0,847)**
	1-150	61	30	31	79,65	31,50	369 (0,085)	0,379 (0,541)**
	5-150	39	23	16	37,20	14,45	158 (0,233)	0,444 (0,510)**
	1-200	46	27	19	78,40	117,30	255 (0,491)	0,233 (0,632)**
	2-200	37	21	16	109	181,35	161 (0,422)	3,393 (0,074)**

Sonae SGPS	1-50	132	66	66	4 266,35	4 331,10	2 126 (0,408)	0,044 (0,835)**
	1-150	87	47	40	4 561,60	5 040,15	868 (0,272)	0,085 (0,772)**
	5-150	57	27	30	5 546,50	4 763,90	356 (0,221)	0,001 (0,974)**
	1-200	61	30	31	5 824,50	4 023,60	417 (0,248)	1,074 (0,304)**
	2-200	55	23	32	4 785,80	3 684,25	345 (0,352)	0,153 (0,697)**

4.4. REGRESSION ANALYSIS

The previous tests have shown some statistical evidence of different behaviors between buy and sell periods following price moving average rules signals. These differences are seen both in prices and volumes. It is then important to investigate the correlation between prices and volume by regressing price moving average and volume on return.

The model is defined by the following equation, according to Campbell et al. (1993), using daily price moving average signals, volume and one-day-lag volume interacted with one-day-lag returns as regressors to explain individual stock price returns:

$$return_t = \alpha + \beta\ signal_t + (\gamma_1 vol_t + \gamma_2 vol_{t-1}) return_{t-1} + \varepsilon_t \qquad (5)$$

We consider the series of the 1-200 moving average rule signals as it is referenced to be the most popular one and returned consistent results in the statistical testing. In order to work with stationary time series in our empirical study, we use the 1st difference log volume series, similarly to Campbell et al. (1993). Figure 3 shows the stationary volume series (see Figure A.10 in the appendix for the raw series), taking the example of BCP.

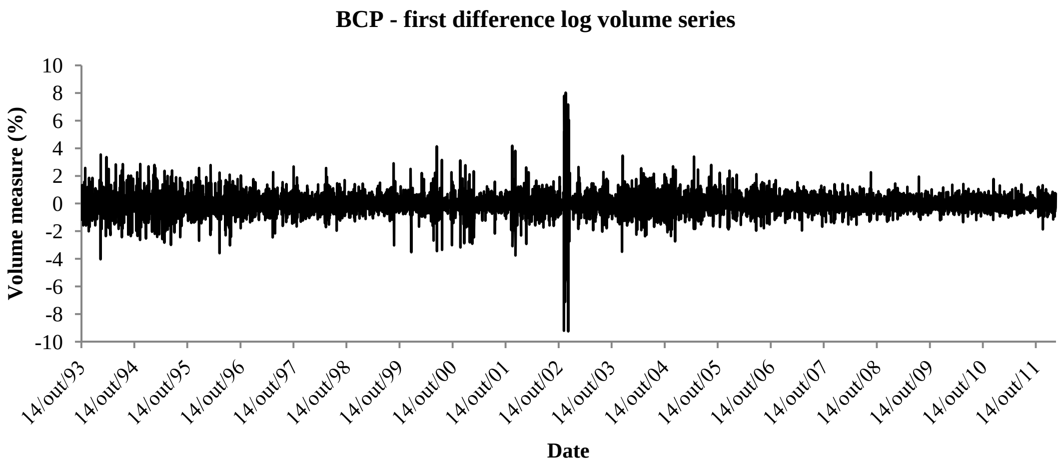

FIGURE 3: STATIONARY LOG TURNOVER SERIES, TOTAL SAMPLE

Our transformed series show no trend signs. Finally, to measure stock return volatility we compare the results using a generalized autoregressive heteroskedasticity (GARCH(1,1)) and the exponential generalized autoregressive heteroskedasticity (EGARCH(1,1)). These models allow us to correct the residual autocorrelation. The EGARCH differs from the standard GARCH model by allowing negative returns to increase volatility more than the positive ones. Both models use minimum likelihood method estimation. The model is selected according to the minimum method selection criterion and only that one is presented in Table V. Asterisk marks the use of EGARCH instead of GARCH model.

Table V presents the coefficients of the regression of current stock return on the moving average signals as well as the current and last day volume interacted with one-day-lag stock return. We conduct two separate analyses: first, we regress current stock return on the moving average signals; and second, an alternative regression includes the current volume and lagged volume interacted with the last day stock return. Results in Table V are based on the total sample.

TABLE V: REGRESSION ON MOVING AVERAGE SIGNALS AND VOLUME INTERACTED WITH PAST RETURN

$$return_t = \alpha + \beta\ signal_t + (\gamma_1 vol_t + \gamma_2 vol_{t-1})return_{t-1} + \varepsilon_t$$

Each stock of the list in the column *Stocks* has two lines presenting the coefficients of two regressions on current return in accordance to the equation above. The four following columns show respectively the coefficients of the constant, the 1-200 moving average rule signal, the current volume interacted with the one-day-lag stock return and the one-day-lag volume interacted with the one-day-lag stock return. The volume series is presented in log differences. Last column is the R^2 statistic of the regression in the respective line. The values marked with an asterisk show the R^2 of the regression using the EGARCH instead of the GARCH model.

Stocks	**α (s.e.)**	**β (s.e.)**	**γ1 (s.e.)**	**γ2 (s.e.)**	R^2
BCP					
Signals	-0.0009 (0.0002)	0.0019 (0.0003)			0.005*
Signals and volume	0.0002 (0.0002)	0.0009 (0.0002)	0.0486 (0.0152)	0.1720 (0.0189)	0.015*
BES					
Signals	-0.0007 (0.0002)	0.0016 (0.0002)			0.005*
Signals and volume	0.0000 (0.0002)	0.0008 (0.0001)	0.0550 (0.0165)	0.1283 (0.0172)	0.025*
BPI					
Signals	-0.0016 (0.0003)	0.0029 (0.0003)			0.007*
Signals and volume	-0.0001 (0.0002)	0.0015 (0.0002)	0.0419 (0.0182)	0.0935 (0.0173)	-0.003*
Cimpor					
Signals	-0.0011 (0.0003)	0.0020 (0.0003)			0.008*
Signals and volume	-0.0001 (0.0002)	0.0010 (0.0002)	0.0606 (0.0188)	0.1230 (0.0171)	0.011*
Mota-Engil					
Signals	-0.0025 (0.0003)	0.0038 (0.0005)			0.008
Signals and volume	-0.0005 (0.0003)	0.0019 (0.0002)	0.0353 (0.0112)	0.0652 (0.0123)	0.018
Portucel					
Signals	-0.0010 (0.0003)	0.0016 (0.0004)			0.006*
Signals and volume	-0.0002 (0.0002)	0.0009 (0.0002)	0.0628 (0.0219)	0.1142 (0.0124)	0.011*
Portugal Telecom					
Signals	-0.0026 (0.0003)	0.0038 (0.0004)			0.009*
Signals and volume	-0.0006 (0.0002)	0.0018 (0.0019)	0.0829 (0.0280)	0.1759 (0.0239)	0.000*
Semapa					
Signals	-0.0002 (0.0004)	0.0030 (0.0005)			0.008*
Signals and volume	-0.0005 (0.0003)	0.0015 (0.0002)	0.0253 (0.0139)	0.0332 (0.0147)	0.004*
Sonae Indústria					
Signals	-0.0016 (0.0003)	0.0030 (0.0004)			0.007*
Signals and volume	-0.0000 (0.0003)	0.0015 (0.0002)	0.0324 (0.0155)	0.0893 (0.0151)	0.017*
Sonae SGPS					
Signals	-0.0029 (0.0004)	0.0044 (0.0005)			0.009*
Signals and volume	-0.0005 (0.0003)	0.0022 (0.0002)	0.0469 (0.0189)	0.1735 (0.0173)	0.012*

The first line of all stocks in Table V shows that at least 0.5% of the variance of each current stock return can be explained by a regression on current moving average signal. The R^2 statistics for these regressions are low, ranging from 0.5% to 0.9%. It is also true that for all stocks, except for three, the R^2 increases (and in some cases more than doubles) once the interaction between volume and one-day-lag return is included. In this case, the statistic may come up to 2.5%. These results can be seen in the second line of each stock. All regressors are always statistically significant at the 5% level.

Not surprisingly, besides increasing the explanatory power of current stock return, coefficients of volume are consistently positive in influencing the dependent variable. The one-day-lag volume interacted with the one-day-lag return is the regressor taking the principal part in changing the expected stock return.

5. CONCLUSIONS, LIMITATIONS AND FUTURE INVESTIGATION

The most striking feature behind this work is that the use of technical analysis, which uses historical data, may result in higher returns than a simple buy-and-hold strategy, what seems to oppose to the efficient market hypothesis formulation. We investigated one of the simplest and most popular trading rule: the moving average. The empirical analysis on returns for 10 Portuguese stocks based on price moving average rules and the comparison to the buy-and-hold portfolio gave strong suggestion that the market was not efficient because a trader or investor adopting a simple moving average trading rule could obtain additional returns than the simple buy-and-hold portfolio.

This conclusion comes first from the parametric tests run on price returns of individual stocks, where we followed the methodology suggested by Brock et al. (1992) and found that for all stocks, returns conditional on buy signals are, on average, statistically higher than the unconditional one-day return and that the differences between mean buy and mean sell returns are all positive and statistically significant, rejecting the null hypothesis of equality of means at the 5% level, except for a few cases. Additionally, we applied the strategy by simulating a real investment following the price moving average strategy and compare it to the simple buy-and-hold strategy. While the former allows consistent and significant profits for all stocks and all moving average rules, the latter one has a low performance and actually brings to a loss in 40% of them, considering the available data sample of about 20 years back from 28 February 2012.

In the case of volume, no general conclusion of an empirical relationship between price moving average rules and this variable was found on our investigation though in some particular stocks the results from the nonparametric tests suggests that following price moving average signals the median volume of buys is statistically different from the median volume of sells in three out of five rules. As said before, when included in a regression on returns, the variables have got little explanatory power, for it cannot offer significant support to the empirical tests run before this analysis. Volume and one-day-lag volume, though, interacted with the one-day-lag return regressors can actually double the R^2 of the regression (though it was able to deliver R^2 of only 2.5%) from what it was if the regression included only the price moving average signals as independent variable.

During this work, we came across some situations where we had to take assumptions on hypothesis that are worth to be pointed out as they may offer some limitations to the conclusions above. Firstly, we did not consider any transaction costs when simulating the returns of the strategies in Chapter 2, what is not realistic as a trader or investor would have to pay commissions or brokerage fees whenever they buy or sell the stocks. In addition, we decided to use parametric tests over distributions that were not clearly normal. It does not seem to be a very problematic choice because the distribution of returns suggests only slight non-normality and in reality one cannot expect to obtain a perfectly normal distribution.

We suggest those who think in pursuing further investigation in this issue to take into account the transaction costs and brokerage fees in the performance analysis, as well as study different and more elaborate rules and test their effectiveness.

To solve the non-synchronous trading problem, we also suggest creating an index-weighted portfolio and compare the results with the index itself in order to bring additional robustness to the analysis.

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APPENDIX

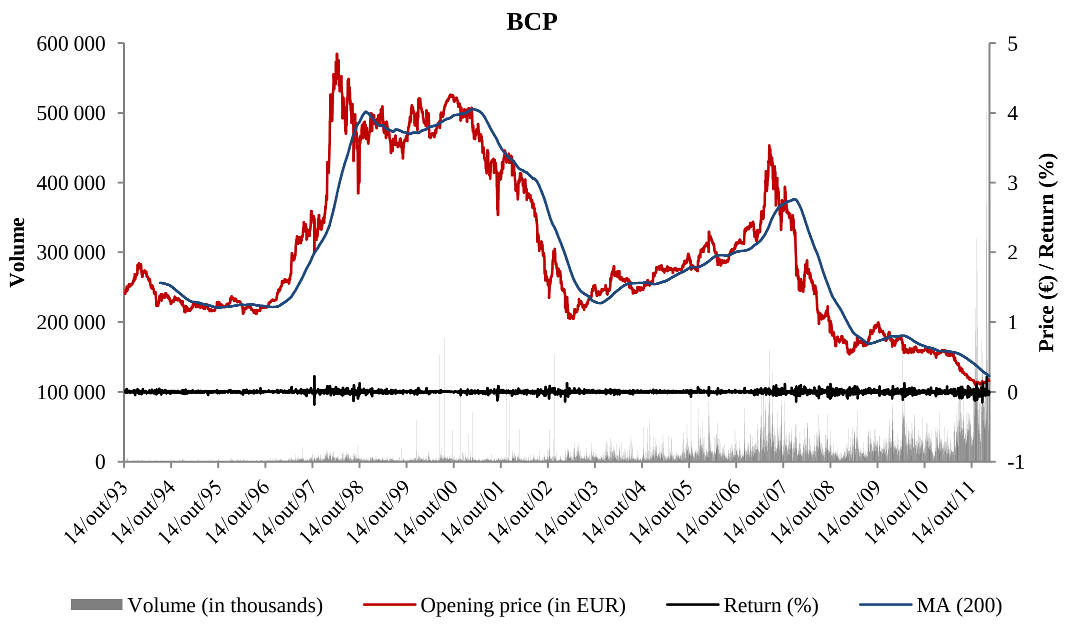

FIGURE A.1: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF BANCO COMERCIAL PORTUGUÊS

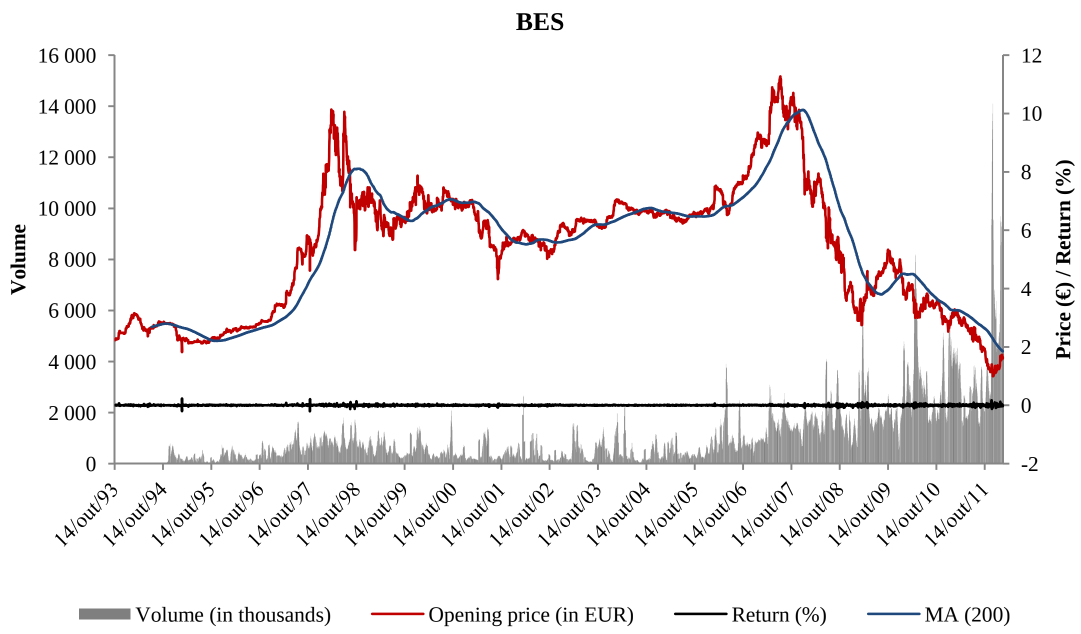

FIGURE A.2: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF BANCO ESPÍRITO SANTO

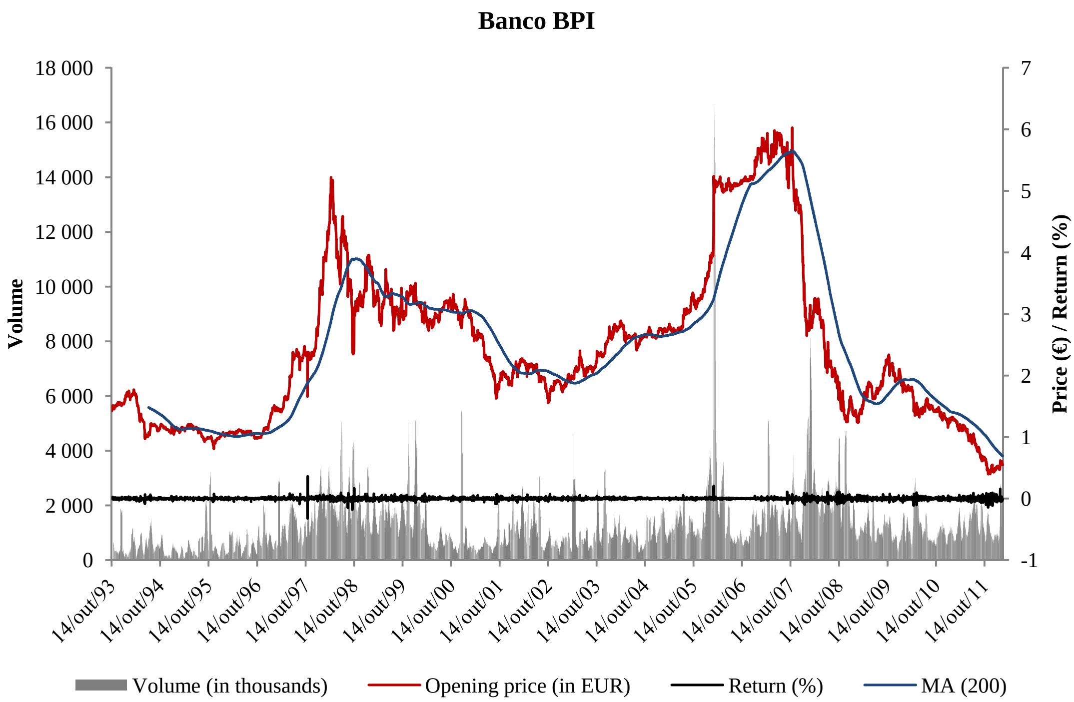

FIGURE A.3: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF BANCO BPI

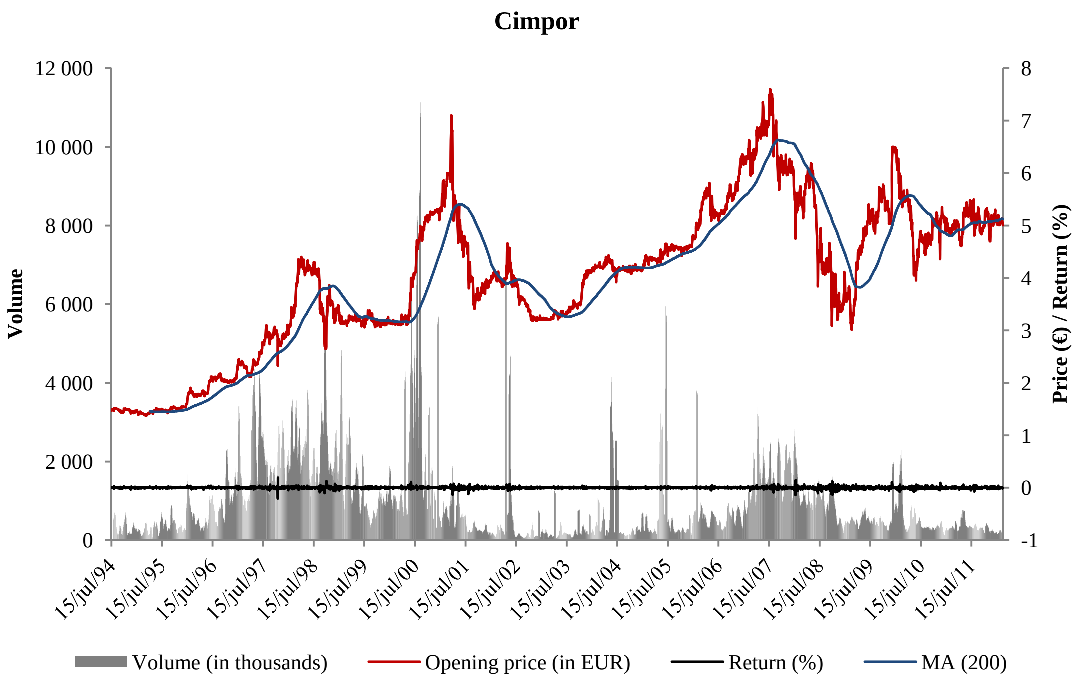

FIGURE A.4: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF CIMPOR

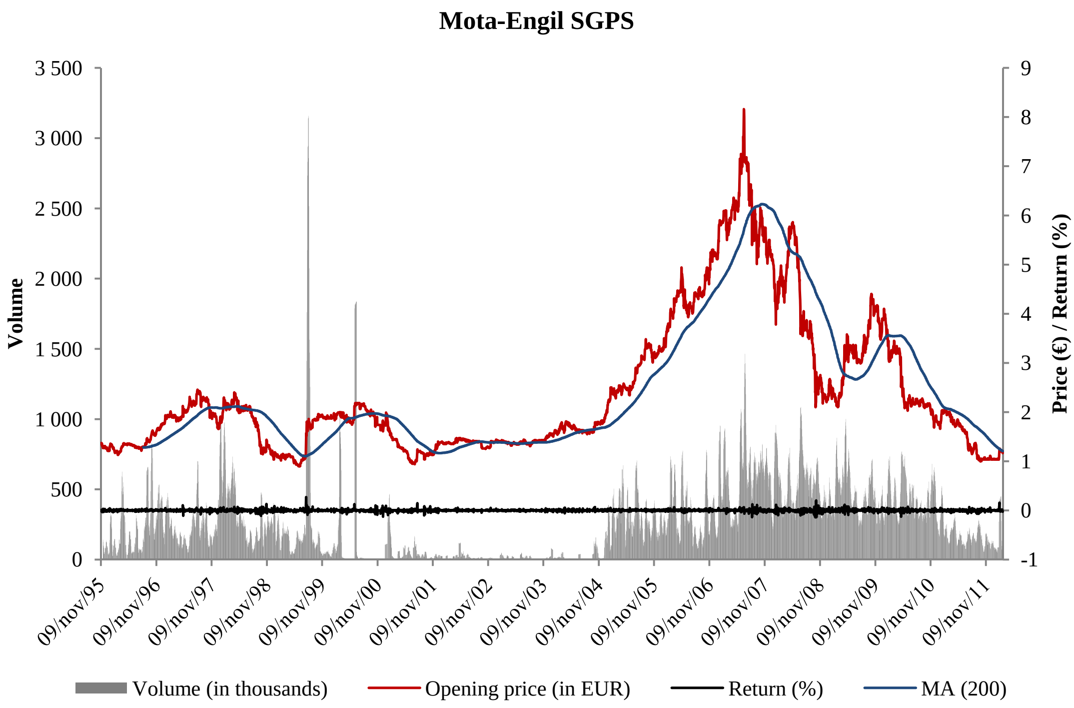

FIGURE A.5: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF MOTA-ENGIL

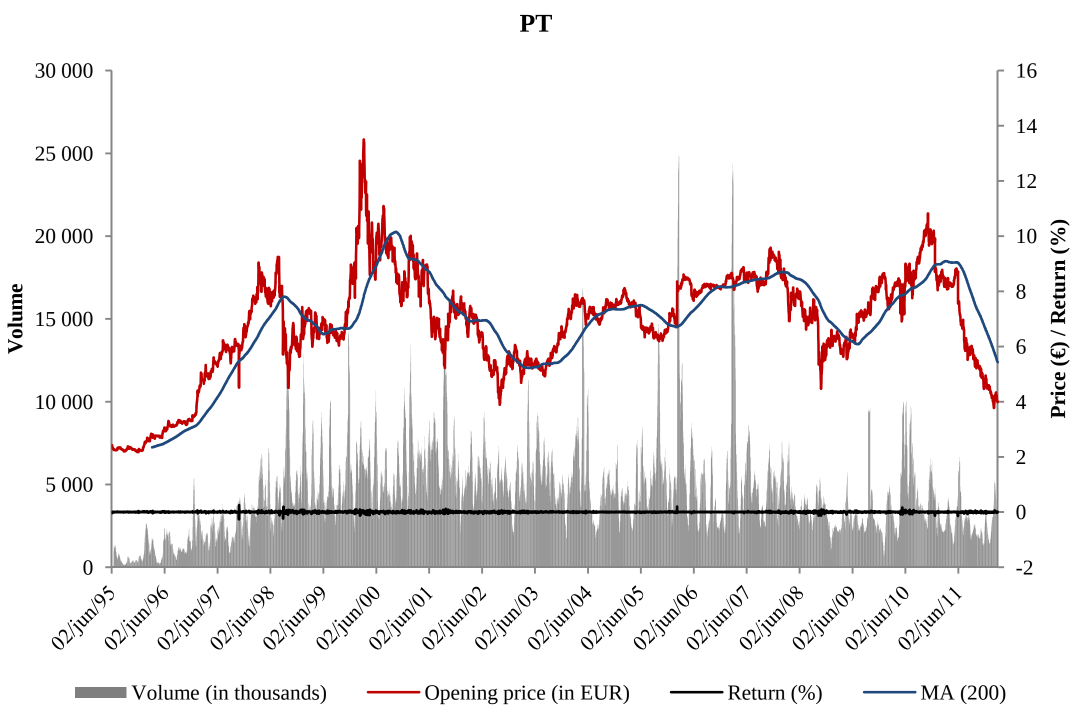

FIGURE A.6: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF PORTUGAL TELECOM

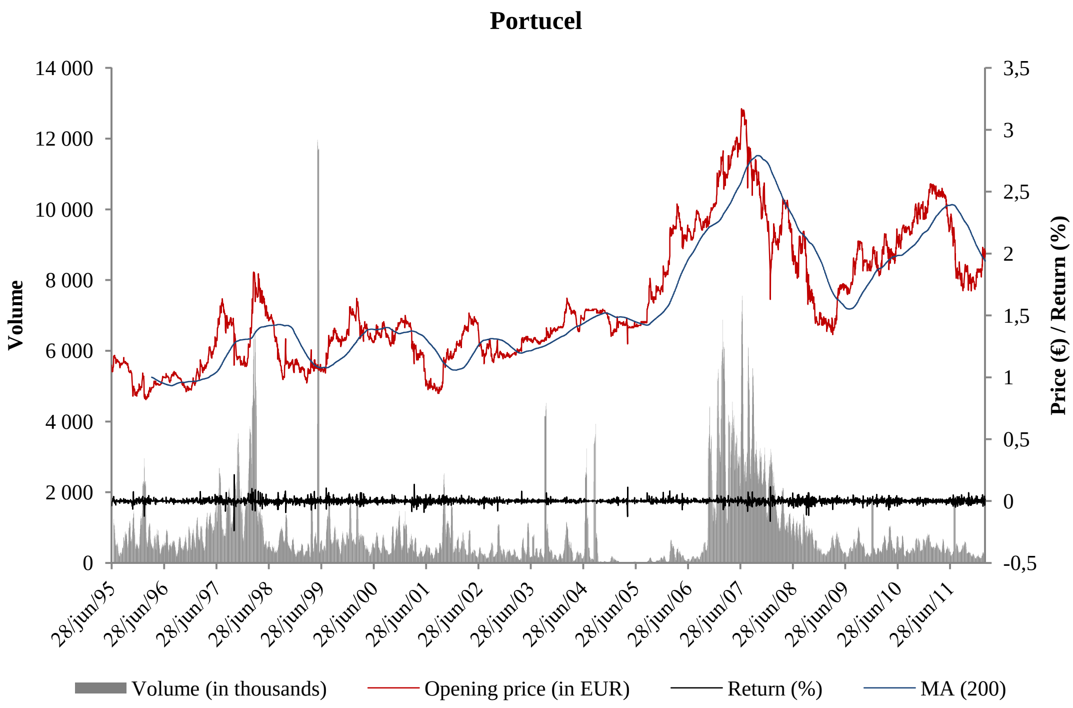

FIGURE A.7: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF PORTUCEL

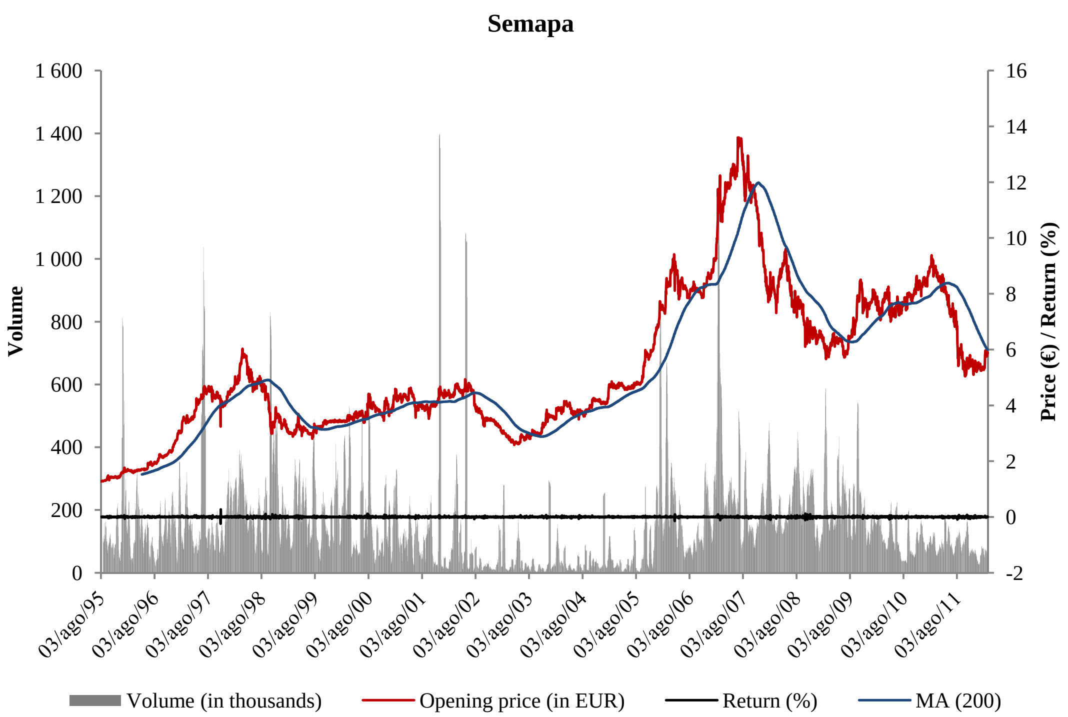

FIGURE A.8: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF SEMAPA

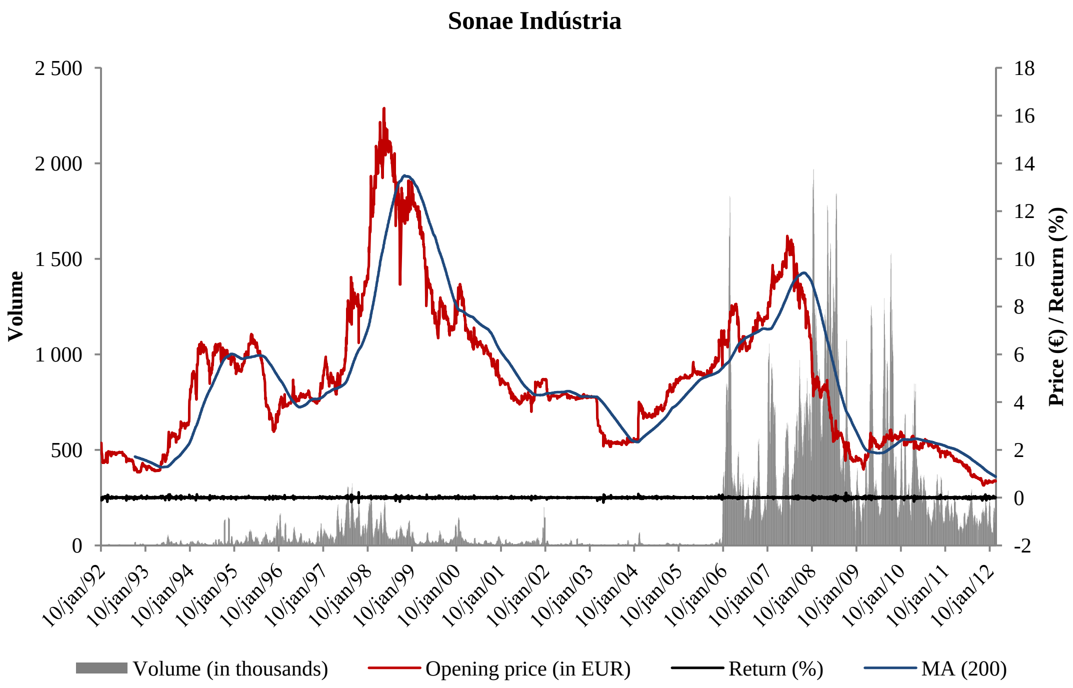

FIGURE A.9: STOCK PRICE, MOVING AVERAGE, RETURN AND VOLUME OF SONAE INDÚSTRIA

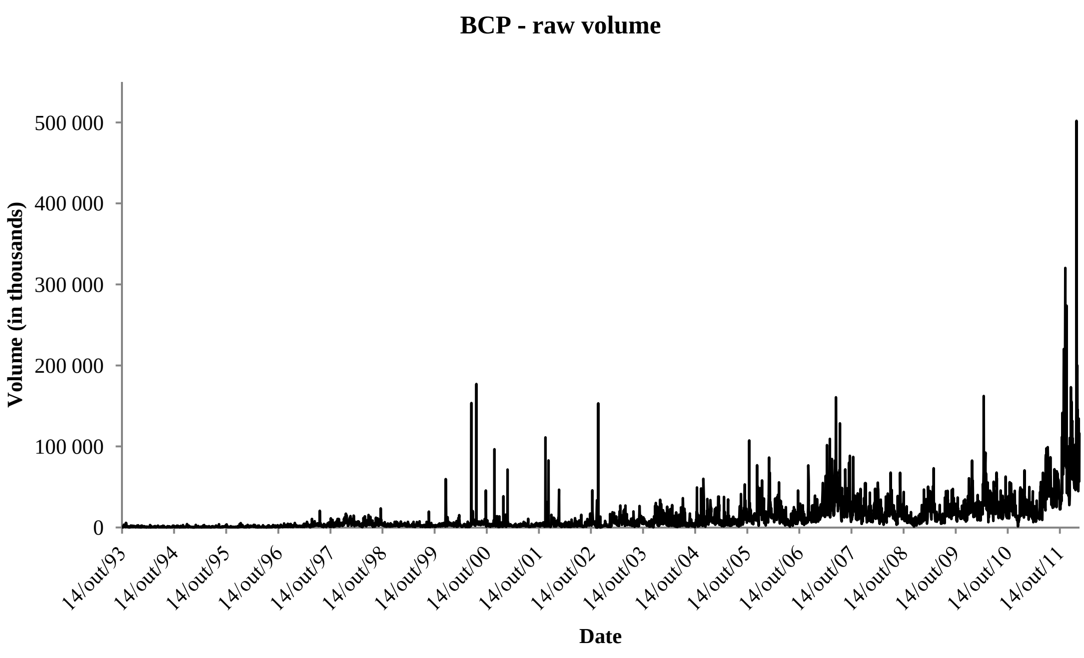

FIGURE A.10: LEVEL OF BCP STOCK VOLUME, TOTAL SAMPLE

TABLE A.1: SUBSAMPLE A - TEST RESULTS ON RETURNS FOR THE MOVING AVERAGE RULES

Results for daily data for subsample A, for each stock. Rules are shown according to the notation "short-long" to define the moving average (MA) strategy with a short period and a long period moving average, respectively. *N buys* and *N sells* are the number of buy and sell signals generated during the period. In *Buy* and *Sell* columns, each cell contains the respective mean return per strategy for each stock and, in brackets, the corresponding p-value of the *t*-test for the difference of the mean buy and mean sell from the unconditional one-day mean presented in Table I. *Buy-Sell* shows the difference between columns *Buy* and *Sell* and the p-value of the *t*-test for the equality of means below, testing the difference (buy-sell) from zero. Numbers marked with an asterisk are statistically significant at the 5% level for a two-tailed test.

Stock	MA strategy	N buys	N sells	Buy	Sell	Buy-Sell
BCP	1-50	591	459	0.0025 (0.001)*	-0.0023 (0.000)*	0.0048 (0.000)*
	1-150	485	465	0.0022 (0.015)*	-0.0013 (0.005)*	0.0035 (0.000)*
	5-150	490	460	0.0014 (0.246)	-0.0005 (0.059)	0.0019 (0.049)*
	1-200	448	453	0.0018 (0.141)	-0.0005 (0.038)*	0.0023 (0.023)*
	2-200	445	456	0.0016 (0.200)	-0.0003 (0.090)	0.0019 (0.054)
	Average	-	-	0,0019	-0,0010	0,0029
BES	1-50	742	309	0.0024 (0.001)*	-0.0029 (0.004)*	0.0053 (0.000)*
	1-150	685	271	0.0015 (0.302)	-0.0010 (0.155)	0.0025 (0.079)
	5-150	675	276	0.0014 (0.394)	-0.0006 (0.269)	0.0020 (0.176)
	1-200	674	227	0.0016 (0.232)	-0.0013 (0.147)	0.0029 (0.030)*
	2-200	673	228	0.0014 (0.376)	-0.0007 (0.277)	0.0021 (0.103)
	Average	-	-	0,0017	-0,0013	0,0030
BPI	1-50	636	415	0.0034 (0.000)*	-0.0040 (0.000)*	0.0074 (0.000)*
	1-150	555	414	0.0017 (0.252)	-0.0022 (0.012)*	0.0039 (0.000)*
	5-150	532	419	0.0014 (0.405)	-0.0003 (0.285)	0.0017 (0.228)
	1-200	512	389	0.0028 (0.013)*	-0.0014 (0.077)	0.0042 (0.003)*
	2-200	509	392	0.0018 (0.244)	-0.0001 (0.394)	0.0019 (0.183)
	Average	-	-	0,0022	-0,0016	0,0038
Cimpor	1-50	531	324	0.0023 (0.001)*	-0.0015 (0.020)*	0.0038 (0.000)*
	1-150	1252	76	0.0019 (0.013)*	-0.0039 (0.101)	0.0058 (0.002)*
	5-150	679	76	0.0009 (0.806)	0.0012 (0.675)	-0.0003 (0.879)
	1-200	683	22	0.0014 (0.192)	-0.0124 (0.178)	0.0138 (0.159)
	2-200	684	21	0.0011 (0.625)	-0.0014 (0.332)	0.0025 (0.446)
	Average	-	-	0,0015	-0,0036	0,0051
Mota-Engil	1-50	302	209	0.0026 (0.017)*	-0.0025 (0.020)*	0.0051 (0.001)*
	1-150	338	73	0.0019 (0.114)	-0.0048 (0.045)*	0.0067 (0.017)*
	5-150	342	69	0.0015 (0.277)	-0.0030 (0.204)	0.0045 (0.124)
	1-200	312	49	0.0016 (0.258)	-0.0039 (0.238)	0.0055 (0.154)
	2-200	312	49	0.0016 (0.258)	-0.0039 (0.238)	0.0055 (0.154)
	Average	-	-	0,0018	-0,0036	0,0055
Portucel	1-50	328	279	0.0027 (0.001)*	-0.0031 (0.037)*	0.0058 (0.000)*
	1-150	330	177	0.0021 (0.044)*	-0.0029 (0.109)	0.0050 (0.010)*
	5-150	328	179	0.0003 (0.770)	0.0005 (0.775)	-0.0002 (0.934)
	1-200	299	220	0.0020 (0.079)	-0.0008 (0.641)	0.0028 (0.024)*
	2-200	298	159	0.0010 (0.272)	-0.0006 (0.788)	0.0016 (0.433)
	Average	-	-	0,0016	-0,0014	0,0030
Portugal Telecom	1-50	490	135	0.0028 (0.022)*	-0.0022 (0.201)	0.0050 (0.007)*
	1-150	518	7	0.0027 (0.117)	-0.0381 (0.333)	0.0408 (0.320)

	5-150	515	10	0.0015 (0.951)	0.0329 (0.233)	-0.0314 (0.233)
	1-200	474	1	0.0024 (0.255)	-0.2630 n.a.	0.2654 n.a.
	2-200	473	2	0,0023 (0.519)	-0.0062 (0.981)	0.0081 (0.980)
	Average	-	-	0,0022	-0,0553	0,0576
Semapa	1-50	482	99	0.0032 (0.054)	-0.0041 (0.124)	0.0073 (0.069)
	1-150	448	33	0.0029 (0.310)	-0.0089 (0.159)	0.0118 (0.130)
	5-150	446	24	0.0022 (0.790)	0.0011 (0.936)	0.0011 (0.922)
	1-200	412	19	0.0030 (0.292)	-0.0146 (0.209)	0.0176 (0.184)
	2-200	411	20	0.0022 (0.767)	0.0029 (0.961)	-0.0007 (0.970)
	Average	-	-	0,0027	-0,0047	0,0074
Sonae Ind.	1-50	742	563	0.0052 (0.000)	-0.0035 (0.000)*	0.0087 (0.000)*
	1-150	867	438	0.0038 (0.012)*	-0.0032 (0.000)*	0.0070 (0.000)*
	5-150	877	428	0.0024 (0.323)	-0.0005 (0.039)*	0.0029 (0.030)*
	1-200	879	426	0.0028 (0.163)	-0.0013 (0.003)*	0.0031 (0.002)*
	2-200	875	430	0.0027 (0.212)	-0.0010 (0.008)*	0.0037 (0.006)*
	Average	-	-	0,0034	-0,0019	0,0051
Sonae SGPS	1-50	717	334	0.0034 (0.010)*	-0.0031 (0.001)*	0.0065 (0.000)*
	1-150	715	236	0.0024 (0.104)	-0.0030 (0.005)*	0.0054 (0.000)*
	5-150	709	242	0.0010 (0.514)	0.0012 (0.949)	-0.0002 (0.948)
	1-200	741	160	0.0022 (0.180)	-0.0034 (0.024)*	0.0056 (0.001)*
	2-200	742	159	0.0014 (0.783)	-0.0001 (0.643)	0.0015 (0.617)
	Average	-	-	0,0021	-0,0017	0,0038

TABLE A.2: SUBSAMPLE B - TEST RESULTS ON RETURNS FOR THE MOVING AVERAGE RULES

Results for daily data for subsample B, for each stock. Rules are shown according to the notation "short-long" to define the moving average (MA) strategy with a short period and a long period moving average, respectively. *N buys* and *N sells* are the number of buy and sell signals generated during the period. In *Buy* and *Sell* columns, each cell contains the respective mean return per strategy for each stock and, in brackets, the corresponding p-value of the *t*-test for the difference of the mean buy and mean sell from the unconditional one-day mean presented in Table I. *Buy-Sell* shows the difference between columns *Buy* and *Sell* and the p-value of the *t*-test for the equality of means below, testing the difference (buy-sell) from zero. Numbers marked with an asterisk are statistically significant at the 5% level for a two-tailed test.

Stock	MA strategy	N buys	N sells	Buy	Sell	Buy-Sell
BCP	1-50	568	736	0.0033 (0.000)*	-0.0031 (0.000)*	0.0064 (0.000)*
	1-150	522	782	0.0019 (0.002)*	-0.0017 (0.044)*	0.0036 (0.000)*
	5-150	523	781	0.0005 (0.250)	-0.0009 (0.427)	0.0014 (0.168)
	1-200	529	775	0.0020 (0.001)*	-0.0018 (0.031)*	0.0038 (0.000)*
	2-200	524	780	0.0010 (0.070)	-0.0012 (0.229)	0.0022 (0.033)*
	Average	-	-	0,0017	-0,0017	0,0035
BES	1-50	650	654	0.0030 (0.000)*	-0.0029 (0.000)*	0.0059 (0.000)*
	1-150	564	771	0.0015 (0.024)*	-0.0014 (0.027)*	0.0029 (0.000)*
	5-150	526	778	0.0004 (0.521)	-0.0002 (0.744)	0.0006 (0.494)
	1-200	550	754	0.0016 (0.017)*	-0.0011 (0.090)	0.0027 (0.004)*
	2-200	542	762	0.0009 (0.180)	-0.0006 (0.371)	0.0015 (0.120)
	Average	-	-	0,0015	-0,0012	0,0027
BPI	1-50	595	709	0.0033 (0.000)*	-0.0032 (0.000)*	0.0065 (0.000)*
	1-150	579	772	0.0011 (0.122)	-0.0014 (0.027)*	0.0028 (0.002)*

	5-150	532	772	0.0001 (0.695)	-0.0005 (0.747)	0.0006 (0.625)
	1-200	507	797	0.0018 (0.020)*	-0.0015 (0.106)	0.0033 (0.007)*
	2-200	506	798	0.0009 (0.178)	-0.0010 (0.338)	0.0019 (0.115)
	Average	-	-	0,0014	-0,0015	0,0030
Cimpor	1-50	621	683	0.0029 (0.000)*	-0.0025 (0.000)*	0.0054 (0.000)*
	1-150	573	731	0.0023 (0.003)*	-0.0017 (0.008)*	0.0040 (0.000)*
	5-150	577	727	0.0013 (0.107)	-0.0009 (0.129)	0.0024 (0.027)*
	1-200	524	780	0.0024 (0.002)*	-0.0015 (0.008)*	0.0039 (0.000)*
	2-200	518	786	0.0013 (0.130)	-0.0008 (0.143)	0.0021 (0.037)*
	Average	-	-	0,0020	-0,0015	0,0036
Mota-Engil	1-50	547	756	0.0048 (0.000)*	-0.0038 (0.000)*	0.0086 (0.000)*
	1-150	610	693	0.0027 (0.001)*	-0.0026 (0.010)*	0.0053 (0.000)*
	5-150	612	691	0.0011 (0.128)	-0.0013 (0.245)	0.0024 (0.059)
	1-200	601	702	0.0025 (0.002)*	-0.0025 (0.017)*	0.0050 (0.000)*
	2-200	595	709	0.0014 (0.075)	-0.0014 (0.199)	0.0028 (0.032)*
	Average	-	-	0,0025	-0,0023	0,0048
Portucel	1-50	609	695	0.0036 (0.000)*	-0.0031 (0.000)*	0.0067 (0.000)*
	1-150	597	707	0.0022 (0.009)*	-0.0018 (0.015)*	0.0040 (0.000)*
	5-150	600	704	0.0005 (0.534)	-0.0004 (0.631)	0.0009 (0.435)
	1-200	605	738	0.0019 (0.020)*	-0.0009 (0.243)	0.0028 (0.001)*
	2-200	604	700	0.0006 (0.489)	-0.0004 (0.575)	0.0010 (0.374)
	Average	-	-	0,0018	-0,0013	0,0031
Portugal Telecom	1-50	597	707	0.0050 (0.000)*	-0.0045 (0.000)*	0.0095 (0.000)*
	1-150	608	696	0.0032 (0.001)*	-0.0031 (0.003)*	0.0063 (0.000)*
	5-150	603	709	-0.0005 (0.753)	0.0002 (0.924)	-0.0007 (0.647)
	1-200	583	721	0.0026 (0.009)*	-0.0024 (0.014)*	0.0050 (0.000)*
	2-200	587	717	0.0005 (0.501)	-0.0007 (0.368)	0.0012 (0.418)
	Average	-	-	0,0022	-0,0021	0,0043
Semapa	1-50	663	641	0.0028 (0.000)*	-0.0034 (0.000)*	0.0062 (0.000)*
	1-150	725	579	0.0011 (0.052)	-0.0019 (0.053)	0.0030 (0.007)*
	5-150	731	573	0.0002 (0.526)	-0.0008 (0.500)	0.0010 (0.358)
	1-200	769	535	0.0011 (0.034)*	-0.0022 (0.028)*	0.0033 (0.003)*
	2-200	767	537	0.0005 (0.257)	-0.0013 (0.244)	0.0018 (0.110)
	Average	-	-	0,0011	-0,0019	0,0031
Sonae Ind.	1-50	475	828	0.0039 (0.000)*	-0.0032 (0.000)*	0.0071 (0.000)*
	1-150	307	997	0.0031 (0.006)*	-0.0017 (0.069)	0.0048 (0.001)*
	5-150	308	996	0.0012 (0.157)	-0.0011 (0.385)	0.0023 (0.098)
	1-200	303	1001	0.0020 (0.042)*	-0.0014 (0.214)	0.0034 (0.018)*
	2-200	301	1003	0.0010 (0.218)	-0.0011 (0.462)	0.0021 (0.152)
	Average	-	-	0,0022	-0,0017	0,0039
Sonae SGPS	1-50	520	784	0.0041 (0.000)*	-0.0045 (0.001)*	0.0086 (0.000)*
	1-150	425	879	0.0031 (0.002)*	-0.0031 (0.027)*	0.0062 (0.000)*
	5-150	423	881	0.0008 (0.144)	-0.0020 (0.339)	0.0028 (0.081)
	1-200	441	863	0.0018 (0.032)*	-0.0025 (0.120)	0.0043 (0.007)*
	2-200	439	865	0.0012 (0.088)	-0.0022 (0.226)	0.0034 (0.034)*
	Average	-	-	0,0022	-0,0029	0,0051

TABLE A.3: SUBSAMPLE C - TEST RESULTS ON RETURNS FOR THE MOVING AVERAGE RULES

Results for daily data for subsample C, for each stock. Rules are shown according to the notation "short-long" to define the moving average (MA) strategy with a short period and a long period moving average, respectively. *N buys* and *N sells* are the number of buy and sell signals generated during the period. In *Buy* and *Sell* columns, each cell contains the respective mean return per strategy for each stock and, in brackets, the corresponding p-value of the *t*-test for the difference of the mean buy and mean sell from the unconditional one-day mean presented in Table I. *Buy-Sell* shows the difference between columns *Buy* and *Sell* and the p-value of the *t*-test for the equality of means below, testing the difference (buy-sell) from zero. Numbers marked with an asterisk are statistically significant at the 5% level for a two-tailed test.

Stock	MA strategy	N buys	N sells	Buy	Sell	Buy-Sell
BCP	1-50	735	568	0.0026 (0.000)*	-0.0027 (0.000)*	0.0053 (0.000)*
	1-150	852	452	0.0014 (0.028)*	-0.0017 (0.019)*	0.0031 (0.002)*
	5-150	854	449	0.0007 (0.373)	-0.0005 (0.374)	0.0012 (0.228)
	1-200	860	444	0.0012 (0.085)	-0.0014 (0.050)*	0.0026 (0.010)*
	2-200	862	442	0.0008 (0.333)	-0.0006 (0.272)	0.0014 (0.150)
	Average	-	-	0,0013	-0,0014	0,0027
BES	1-50	733	571	0.0016 (0.000)*	-0.0012 (0.000)*	0.0028 (0.000)*
	1-150	902	422	0.0007 (0.102)	-0.0008 (0.001)*	0.0015 (0.000)*
	5-150	886	418	0.0005 (0.328)	-0.0001 (0.267)	0.0006 (0.142)
	1-200	925	379	0.0008 (0.038)*	-0.0009 (0.001)*	0.0017 (0.000)*
	2-200	929	375	0.0006 (0.276)	-0.0003 (0.095)	0.0009 (0.046)*
	Average	-	-	0,0008	-0,0007	0,0015
BPI	1-50	910	394	0.0020 (0.004)*	-0.0023 (0.000)*	0.0043 (0.000)*
	1-150	1147	256	0.0011 (0.269)	-0.0027 (0.000)*	0.0038 (0.000)*
	5-150	1055	249	0.0010 (0.485)	-0.0005 (0.193)	0.0015 (0.142)
	1-200	1090	214	0.0013 (0.140)	-0.0023 (0.003)*	0.0036 (0.001)*
	2-200	1087	216	0.0010 (0.471)	-0.0008 (0.163)	0.0018 (0.120)
	Average	-	-	0,0013	-0,0017	0,0030
Cimpor	1-50	906	397	0.0019 (0.000)*	-0.0027 (0.000)*	0.0046 (0.000)*
	1-150	983	321	0.0011 (0.073)	-0.0014 (0.004)*	0.0025 (0.000)*
	5-150	976	327	0.0007 (0.635)	0.0000 (0.353)	0.0007 (0.306)
	1-200	1005	299	0.0010 (0.116)	-0.0013 (0.010)*	0.0023 (0.001)*
	2-200	1008	296	0.0007 (0.654)	-0.0001 (0.344)	0.0008 (0.297)
	Average	-	-	0,0011	-0,0011	0,0022
Mota-Engil	1-50	863	441	0.0030 (0.000)*	-0.0030 (0.000)*	0.0060 (0.000)*
	1-150	1044	260	0.0018 (0.098)	-0.0023 (0.017)*	0.0041 (0.005)*
	5-150	1052	252	0.0013 (0.491)	-0.0005 (0.277)	0.0018 (0.121)
	1-200	1077	227	0.0016 (0.175)	-0.0022 (0.028)*	0.0038 (0.121)
	2-200	1074	230	0.0013 (0.476)	-0.0007 (0.238)	0.0020 (0.091)
	Average	-	-	0,0018	-0,0017	0,0035
Portucel	1-50	856	446	0.0019 (0.001)*	-0.0021 (0.001)*	0.0040 (0.000)*
	1-150	984	320	0.0012 (0.074)	-0.0016 (0.027)*	0.0028 (0.006)*
	5-150	988	316	0.0008 (0.384)	-0.0005 (0.304)	0.0013 (0.202)
	1-200	979	351	0.0011 (0.128)	-0.0006 (0.234)	0.0017 (0.005)*
	2-200	976	327	0.0009 (0.319)	-0.0006 (0.210)	0.0015 (0.076)
	Average	-	-	0,0012	-0,0011	0,0023
Portugal Telecom	1-50	749	555	0.0021 (0.000)*	-0.0020 (0.000)*	0.0041 (0.000)*
	1-150	898	406	0.0012 (0.062)	-0.0015 (0.001)*	0.0027 (0.000)*

	5-150	889	415	0.0003 (0.755)	0.0006 (0.788)	-0.0003 (0.689)
	1-200	957	347	0.0011 (0.106)	-0.0016 (0.002)*	0.0027 (0.001)*
	2-200	965	339	0.0006 (0.627)	-0.0003 (0.267)	0.0009 (0.245)
	Average	-	-	0,0011	-0,0010	0,0020
Semapa	1-50	805	497	0.0031 (0.000)*	-0.0031 (0.000)*	0.0062 (0.000)*
	1-150	928	376	0.0020 (0.013)*	-0.0023 (0.000)*	0.0043 (0.000)*
	5-150	919	385	0.0013 (0.218)	-0.0007 (0.052)	0.0020 (0.028)*
	1-200	1019	285	0.0015 (0.086)	-0.0021 (0.001)*	0.0036 (0.000)*
	2-200	1017	287	0.0014 (0.155)	-0.0016 (0.006)*	0.0030 (0.003)*
	Average	-	-	0,0019	-0,0020	0,0038
Sonae Ind.	1-50	817	487	0.0033 (0.000)*	-0.0046 (0.000)*	0.0079 (0.000)*
	1-150	885	419	0.0018 (0.020)*	-0.0028 (0.007)*	0.0046 (0.001)*
	5-150	895	409	0.0013 (0.134)	-0.0018 (0.071)	0.0031 (0.022)*
	1-200	891	413	0.0018 (0.025)*	-0.0028 (0.007)*	0.0046 (0.001)*
	2-200	887	417	0.0014 (0.101)	-0.0019 (0.047)*	0.0035 (0.012)*
	Average	-	-	0,0019	-0,0028	0,0047
Sonae SGPS	1-50	911	393	0.0035 (0.001)*	-0.0031 (0.000)*	0.0066 (0.000)*
	1-150	996	308	0.0024 (0.110)	-0.0014 (0.012)*	0.0038 (0.001)*
	5-150	985	319	0.0016 (0.857)	0.0011 (0.715)	0.0005 (0.676)
	1-200	1123	181	0.0019 (0.448)	-0.0011 (0.117)	0.0030 (0.085)
	2-200	1122	182	0.0017 (0.769)	0.0004 (0.535)	0.0013 (0.497)
	Average	-	-	0,0022	-0,0008	0,0030

TABLE A.4: SUBSAMPLE D - TEST RESULTS ON RETURNS FOR THE MOVING AVERAGE RULES

Results for daily data for subsample D, for each stock. Rules are shown according to the notation "short-long" to define the moving average (MA) strategy with a short period and a long period moving average, respectively. *N buys* and *N sells* are the number of buy and sell signals generated during the period. In *Buy* and *Sell* columns, each cell contains the respective mean return per strategy for each stock and, in brackets, the corresponding p-value of the *t*-test for the difference of the mean buy and mean sell from the unconditional one-day mean presented in Table I. *Buy-Sell* shows the difference between columns *Buy* and *Sell* and the p-value of the *t*-test for the equality of means below, testing the difference (buy-sell) from zero. Numbers marked with an asterisk are statistically significant at the 5% level for a two-tailed test.

Stock	MA strategy	N buys	N sells	Buy	Sell	Buy-Sell
BCP	1-50	336	750	0.0042 (0.000)*	-0.0055 (0.007)*	0.0097 (0.000)*
	1-150	180	905	0.0029 (0.001)*	-0.0036 (0.301)	0.0065 (0.001)*
	5-150	177	909	-0.0013 (0.461)	-0.0028 (0.807)	0.0041 (0.454)
	1-200	127	959	0.0026 (0.004)*	-0.0032 (0.487)	0.0058 (0.004)*
	2-200	128	958	0.0006 (0.081)	-0.0029 (0.665)	0.0035 (0.084)
	Average	-	-	0,0018	-0,0036	0,0059
BES	1-50	359	727	0.0050 (0.000)*	-0.0049 (0.002)*	0.0099 (0.000)*
	1-150	227	870	0.0013 (0.037)*	-0.0026 (0.315)	0.0039 (0.000)*
	5-150	211	875	-0.0002 (0.289)	-0.0020 (0.698)	0.0022 (0.280)
	1-200	152	934	0.0027 (0.003)*	-0.0023 (0.437)	0.0050 (0.003)*
	2-200	149	937	0.0010 (0.064)*	-0.0021 (0.635)	0.0031 (0.072)
	Average	-	-	0,0020	-0,0028	0,0048
BPI	1-50	317	769	0.0053 (0.000)*	-0.0050 (0.006)*	0.0103 (0.000)*
	1-150	205	892	0.0013 (0.017)*	-0.0028 (0.431)	0.0041 (0.008)*

	5-150	193	893	0.0014 (0.022)*	-0.0027 (0.496)	0.0041 (0.023)*
	1-200	198	888	0.0011 (0.027)*	-0.0027 (0.520)	0.0038 (0.003)*
	2-200	199	887	0.0008 (0.045)*	-0.0026 (0.563)	0.0034 (0.050)*
	Average	-	-	0,0020	-0,0032	0,0051
Cimpor	1-50	353	551	0.0039 (0.000)*	-0.0041 (0.001)*	0.0080 (0.000)*
	1-150	493	593	0.0022 (0.002)*	-0.0022 (0.072)	0.0044 (0.000)*
	5-150	497	589	-0.001 (0.863)	-0.0003 (0.956)	0.0004 (0.001)*
	1-200	499	587	0.0021 (0.004)*	-0.0021 (0.089)	0.0042 (0.887)
	2-200	500	586	0.0008 (0.192)	-0.0010 (0.475)	0.0018 (0.185)
	Average	-	-	0,0016	-0,0019	0,0038
Mota-Engil	1-50	362	724	0.0051 (0.000)*	-0.0046 (0.002)*	0.0097 (0.000)*
	1-150	283	803	0.0020 (0.026)*	-0.0026 (0.234)	0.0046 (0.014)*
	5-150	284	802	0.0005 (0.182)	-0.0020 (0.531)	0.0025 (0.177)
	1-200	247	839	0.0016 (0.062)	-0.0022 (0.391)	0.0038 (0.054)
	2-200	248	838	0.0009 (0.148)	-0.0020 (0.521)	0.0029 (0.143)
	Average	-	-	0,0020	-0,0027	0,0047
Portucel	1-50	530	556	0.0033 (0.000)*	-0.0033 (0.001)*	0.0066 (0.000)*
	1-150	569	517	0.0019 (0.001)*	-0.0023 (0.034)*	0.0042 (0.001)*
	5-150	565	521	0.0006 (0.256)	-0.0009 (0.459)	0.0015 (0.223)
	1-200	547	558	0.0015 (0.007)*	0.0012 (0.251)	0.0027 (0.005)*
	2-200	551	535	0.0007 (0.148)	-0.0010 (0.385)	0.0017 (0.146)
	Average	-	-	0,0016	-0,0013	0,0033
Portugal Telecom	1-50	489	597	0.0033 (0.000)*	-0.0041 (0.001)*	0.0074 (0.000)*
	1-150	414	672	0.0030 (0.000)*	-0.0030 (0.012)*	0.0060 (0.000)*
	5-150	410	676	0.0004 (0.226)	-0.0041 (0.431)	0.0018 (0.157)
	1-200	409	677	0.0025 (0.001)*	-0.0027 (0.033)*	0.0052 (0.000)*
	2-200	411	675	0.0007 (0.143)	-0.0016 (0.346)	0.0023 (0.088)
	Average	-	-	0,0020	-0,0031	0,0045
Semapa	1-50	475	611	0.0043 (0.000)*	-0.0040 (0.000)*	0.0083 (0.000)*
	1-150	426	660	0.0023 (0.000)*	-0.0021 (0.068)	0.0044 (0.000)*
	5-150	423	663	0.000 (0.577)	-0.0006 (0.802)	0.0006 (0.579)
	1-200	400	686	0.0018 (0.007)*	-0.0016 (0.170)	0.0034 (0.005)*
	2-200	390	690	0.0005 (0.258)	-0.0009 (0.579)	0.0014 (0.238)
	Average	-	-	0,0018	-0,0018	0,0036
Sonae Ind.	1-50	303	783	0.0054 (0.000)*	-0.0050 (0.011)*	0.0104 (0.000)*
	1-150	245	841	0.0024 (0.005)*	-0.0034 (0.243)	0.0058 (0.003)*
	5-150	242	844	0.0010 (0.057)	-0.0030 (0.429)	0.0040 (0.043)*
	1-200	233	853	0.0023 (0.009)*	-0.0033 (0.279)	0.0056 (0.014)*
	2-200	232	854	0.0007 (0.085)	-0.0029 (0.493)	0.0038 (0.070)
	Average	-	-	0,0024	-0,0035	0,0059
Sonae SGPS	1-50	398	688	0.0034 (0.000)*	-0.0040 (0.021)*	0.0074 (0.000)*
	1-150	353	733	0.0028 (0.000)*	-0.0032 (0.085)	0.0060 (0.000)*
	5-150	347	739	0.0008 (0.039)*	-0.0023 (0.380)	0.0031 (0.039)*
	1-200	360	726	0.0023 (0.0000)*	-0.0030 (0.123)	0.0053 (0.000)*
	2-200	362	724	0.0011 (0.014)*	-0.0024 (0.300)	0.0035 (0.016)*
	Average	-	-	0,0021	-0,0030	0,0051

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