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OPTIMIZATION AND TESTING OF MONEY FLOW INDEX

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Abstract. The paper deals with whether the Money Flow Index (MFI) can still be used successfully for trading, and whether the parameters recommended in the literature are the best that an investor can use. Simulations in randomized time interval for the largest companies in the S&P 500 Index show that trading strategy based on MFI may be more profitable than a simple buy-and-hold strategy; however, parameters of MFI need to be optimized because those recommended in the literature do not produce the best results.

Keywords: Money Flow Index, MFI, S&P 500, buy-and-hold, stocks, investment, trading

Mathematics Subject Classification: Primary 91G10; Secondary 62P20

1 Introduction

Money Flow Index (MFI) is an oscillator introduced to improve the Relative Strength Index (RSI) published by Wilder (1978). Authors of MFI, Quong and Soudack (1989), state that MFI measures the strength of money entering and leaving the market. This is – according to the authors – achieved by taking volume into account, as volume can vary widely in market tops and bottoms. They also suggest using more information about the price; therefore, the MFI uses not only the close price but also high and low prices.

The computation of MFI requires to compute *typical price* (TP_t) and *money flow* (MF_t) for each trading day. The typical price is defined as the average of adjusted high (H_t), adjusted low (L_t), and adjusted close (C_t) price, i.e.

$$TP_t = \frac{H_t^a + L_t^a + C_t^a}{3}. \tag{1}$$

We recommend the use of adjusted prices as a decline caused by a dividend payment or a stock split causes false movement in the stock price. This requirement is not usually found in the literature, but we consider it important. The adjusted price (for dividends and splits) is explained in the section *Data*.

The money flow is computed using the typical price and volume (V_t) as

$$MF_t = TP_t \cdot V_t. \tag{2}$$

The *positive money flow* (MF_t^+) over a period of length p is calculated as the sum of money flows on the days when the typical price was higher than the typical price of the previous day (i.e. when $TP_t > TP_{t-1}$). This can be explained by the formula

$$MF_t^+(p) = \sum_{\tau=t-p+1}^{t} \max(0; \operatorname{sgn}(TP_\tau - TP_{\tau-1}) \cdot MF_\tau). \tag{3}$$

The *negative money flow* (MF_t^-) over a period of length p is calculated as the sum of money flows on days when the typical price was lower than the typical price of the previous day (i.e. when $TP_t < TP_{t-1}$). This can be explained by the formula

$$MF_t^-(p) = \sum_{\tau=t-p+1}^{t} \max(0; \operatorname{sgn}(TP_{\tau-1} - TP_\tau) \cdot MF_\tau). \tag{4}$$

The money flow index is calculated as

$$MFI_t(p) = 100 \frac{MF_t^+(p)}{MF_t^+(p) + MF_t^-(p)}. \tag{5}$$

Equation (5) reveals the meaning of MFI: It is the percentage of the positive money flow to the total money flow over a given period. The standard length of period p is 14 days. This parameter will be optimised later in this paper.

Several different approaches can be used to obtain buy or sell signals. All of them use value L ($L \in (0,50)$) of MFI to indicate that stock is oversold and value $100 - L$ to indicate that stock is overbought. The standard value of L is 20, see e.g. Thomsett (2019, pp. 215–217). Quong and Soudack (1989) also used $L = 10$ to indicate *truly oversold* and *truly overbought* stock. This parameter will also be optimized in this paper. We will adopt the same logic for signals as Marek and Šedivá (2017) used for RSI, i.e.:

- Buy signal occurs when the MFI returns to the value L from below.
- Sell signal occurs when the MFI returns to the value $100 - L$ from above.

Other trading techniques are:

- Buy/sell signal occurs when the MFI enters the oversold or overbought zone, see Thomsett (2018, pp. 180) for more details.
- Identifying divergence between the MFI and price, see Thomsett (2019, pp. 215–217) for more details.

Marek and Šedivá (2017) studied RSI and used day-to-day optimization of its parameters. One of the main findings of their paper is that the day-to-day optimization is not recommended as it usually yields worse result than the RSI with the standard parameters. We will build on their findings and instead of the day-to-day optimization we will focus of finding the best combination of parameters p and L.

We will compare optimised MFI with:

- MFI using standard parameters, i.e. $p = 14$ and $L = 20$.
- MFI using parameters set to indicate truly oversold and overbought stock, i.e. $p = 14$ and $L = 10$.
- Simple buy-and-hold strategy.

The main goals of this paper are: to study whether the MFI, more than 30 years after its publication, yields better results than a simple buy-and-hold strategy, and whether different p and L settings can lead to a higher capital appreciation.

2 Data

The first step is to select the companies to be involved in the study. As stated in Marek and Šedivá (2017), this is a key part of the research and must be carried out – if possible – without any information available after the start of simulation, e.g., it is necessary to avoid conscious inclusion or exclusion of companies that performed well or badly after the start of simulation. We will use the same 16 companies as in Marek and Šedivá (2017) because we want to meet similar requirements.

Our simulations start randomly between January 2, 2007 and December 31, 2009 (the interval selection is explained in the section *Methods*); the choice must therefore respect that only information of that period or some previous is used. We identified the largest companies of that time as those involved in the top 10 companies with the highest weight in the S&P 500 Index. The composition of the index for each year was obtained from ETF Database (2019). The first involved companies are those that were involved among the top 10 companies with the highest weight in the S&P 500 Index for the year 2006, i.e. before the start of all simulations. Next, companies involved in the years 2007–2009 are also used. Tab. 1 lists all selected companies, their ticker, and the first year (2006–2009) when they appeared in the top 10 companies with the highest weight in the index.

Company	Ticker	Year
American International Group, Inc.	AIG	2006
Apple Inc.	AAPL	2009
AT&T Inc.	T	2007
Bank of America Corporation	BAC	2006
Chevron Corporation	CVX	2007
Citigroup Inc.	C	2006
Exxon Mobil Corporation	XOM	2006
General Electric Company	GE	2006
Google Inc. (now Alphabet Inc.)	GOOG	2007
International Business Machines Corporation	IBM	2009
Johnson & Johnson	JNJ	2006
JPMorgan Chase & Co.	JPM	2008
Microsoft Corporation	MSFT	2006
Pfizer Inc.	PFE	2006
The Procter & Gamble Company	PG	2006
Walmart Inc.	WMT	2006

Tab. 1. List of companies used in the simulations.

Historical records of high (H_t), low (L_t), close (C_t), and adjusted close (C_t^a) prices were obtained from the website Yahoo! Finance (2019). The adjusted close price contains information about dividends (it is assumed that whenever an investor is entitled to a dividend, he reinvests it immediately in the same stock) and splits, therefore we use this price in our paper rather than the close price. We also use the adjusted close price to obtain the multiplier m_t used in its calculation ($m_t = C_t^a / C_t$) and calculate adjusted high price $H_t^a = m_t \cdot H_t$ and adjusted low price $L_t^a = m_t \cdot L_t$.

We obtained records between June 30, 2006 and July 31, 2019 for each stock listed in Tab. 1. The period before the first investment date is necessary for the calculation of the MFI initial value as at January 2, 2007.

3 Methods

First, we need to determine the starting date of simulation. Again, it has to be selected so that it does not significantly affect the results. This is the main reason for deciding to use an interval instead of one particular date. Each simulation starts randomly in a three-year window. This window is set up to include dates before and after the peak of the financial crisis in 2008. Each simulation starts between January 2, 2007 and December 31, 2009.

The same logic is used in the determination of the end of each simulation, and instead of a single date we use a randomly selected date from the window between January 2, 2015 and July 31, 2019. This means that each simulation lasts a minimum of five years and a maximum of 12 and a half years.

The interval – obtained according to the previous two paragraphs – is used for each simulation round where we calculate annual appreciation of the buy-and-hold strategy, strategies based on the MFI with standard setting, i.e. $p = 14$ and $L = 20$, and the MFI with setting set to indicate truly oversold and overbought stock, i.e. $p = 14$ and $L = 10$. Furthermore, MFI with each remaining combination of $p \in \{5, 6, \dots, 30\}$ and $L \in \{10, 11, \dots, 35\}$ is used to calculate annual appreciation. The lowest value of p is set to cover at least one trading week as lower values can be considered insufficient and the MFI would be highly unstable. The highest value of p is slightly higher than twice the standard setting and covers approximately period of one and half month (30 trading days). Longer periods can cause the MFI to become too stable to generate any trading signal (as confirmed by simulations).

Signal lines at 10 and 90 ($L = 10$) are commonly considered very strict (and produce a small amount of signals), therefore we use this setting as one limit. The second limit is the signal lines at 35 and 65 ($L = 35$), which usually produces large number of signals for MFI, and we can expect many to be false.

The algorithm can be summarized as:

1. Randomly generate a simulation start date between January 2, 2007 and December 31, 2009.
2. Randomly generate a simulation end date between January 2, 2015 and July 31, 2019.
3. Calculate the corresponding annual appreciation for an investor using the buy-and-hold strategy.
4. Calculate the corresponding annual appreciation for an investor using strategy based on MFI with all selected combinations of p and L.

Simulation produces 677 results – one for buy-and-hold strategy and 676 results for the MFI (26 values of p multiplied by 26 values of L). The simulation is repeated 1 000 times (each round with a newly generated start and end of the simulation) for each company, producing 677 000 annual appreciations for each company. 1 000 simulations are enough to produce stable results as shown in Fig. 1 and Fig. 2 for Apple. Both figures demonstrate that the average annual appreciation is stable after approximately 100 simulations. Fig. 1 demonstrates stabilization for MFI with standard parameters $p = 14$ and $L = 20$, and Fig. 2 for MFI with extreme combination of parameters $p = 30$ and $L = 13$, i.e. situation where almost no trades were made (for $p = 30$ and $L \in \{10, 11, 12\}$ we obtained no trade in every simulation). Similar behaviour of stabilization was recorded for each company.

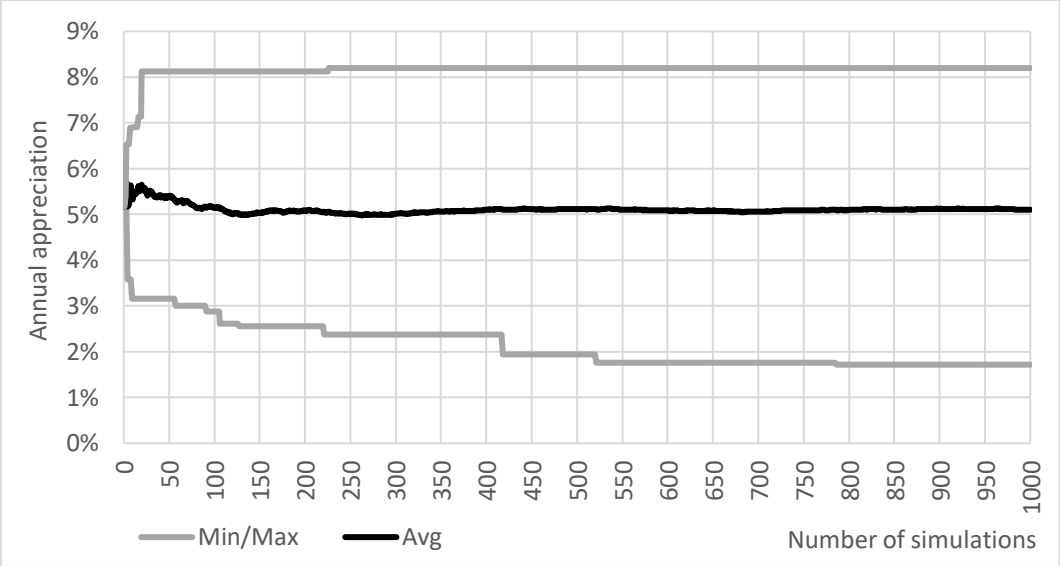

Fig. 1. Minimum, maximum and average annual appreciation for MFI strategy with $p = 14$ and $L = 20$ in dependence on number of simulations for Apple.

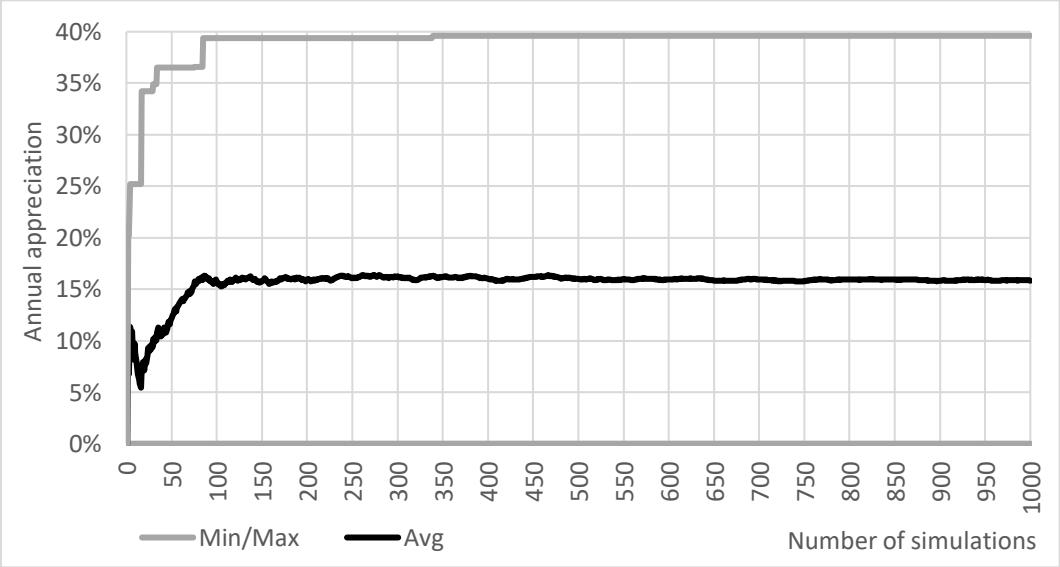

Fig. 2. Minimum, maximum and average annual appreciation for MFI strategy with $p = 30$ and $L = 13$ in dependence on number of simulations for Apple.

The strategy that produces the highest annual capital appreciation is found in each simulation round. This is used to compare strategies, as well as some basic statistical characteristics that are obtained later. For the purpose of presenting the results we recognize:

- buy-and-hold strategy (*B&H*),
- MFI strategy with standard values of parameters $p = 14$ and $L = 20$ (denoted as *MFI(S)*),
- MFI strategy with parameters set to indicate truly oversold and overbought stock $p = 14$ and $L = 10$ (denoted as *MFI(TO)*), and
- the rest of MFI strategies are considered as one group denoted as *MFI(oth.)*.

We also performed the same type of simulations in a shorter time interval to see how the selected time window for trading affects the results. The start date was selected between January 3, 2012 and July 1, 2014, and the end date was selected between January 3, 2017 and July 31, 2019. For the simulations we used the same companies as before. It should be noted that this means that we are no longer dealing with the largest companies of the S&P 500 Index (although some companies were still part of the top 10 companies with the highest weight in the S&P 500 Index), and that the peak of the financial crisis was several years before the interval used to generate the start date.

4 Results

In each of the 1 000 simulations we found the strategy that produced the highest annual appreciation. For the longer time interval (the earliest start date on January 2, 2007 and the latest end date on July 31, 2019) we present results in Tab. 2. As can be seen, the highest annual appreciation was usually achieved by MFI with parameter settings other than those recommended in the literature.

Company	Ticker	B&H	MFI(S)	MFI(TO)	MFI(oth.)
AIG	AIG	6	0	0	994
Apple	AAPL	460	0	0	540
AT&T	T	37	0	0	963
Bank of America	BAC	38	0	0	962
Chevron	CVX	0	0	0	1000
Citigroup.	C	0	0	0	1000
Exxon Mobil	XOM	0	0	0	1000
General Electric	GE	11	0	0	989
Google (Alphabet)	GOOG	285	0	0	715
IBM	IBM	0	0	0	1000
Johnson & Johnson	JNJ	291	0	0	709
JPMorgan Chase	JPM	78	0	0	922
Microsoft	MSFT	243	0	0	757
Pfizer	PFE	265	0	0	735
Procter & Gamble	PG	279	0	0	721
Walmart	WMT	1	0	0	999

Tab. 2. Number of simulations where strategies recorded the highest annual appreciation in the longer time interval, i.e. the earliest start date on January 2, 2007 and the latest end date on July 31, 2019.

For the shorter time interval (the earliest start date on January 3, 2012 and the latest end date on July 31, 2019) we present results in Tab. 3. Again, the highest annual appreciation was usually achieved by MFI with parameter settings other than those recommended in the literature.

Company	Ticker	B&H	MFI(S)	MFI(TO)	MFI(oth.)
AIG	AIG	87	0	0	913
Apple	AAPL	345	0	0	655
AT&T	T	3	17	0	980
Bank of America	BAC	158	0	0	842
Chevron	CVX	0	0	0	1000
Citigroup.	C	0	0	0	1000
Exxon Mobil	XOM	0	0	0	1000
General Electric	GE	0	0	0	1000
Google (Alphabet)	GOOG	34	0	0	966
IBM	IBM	0	0	0	1000
Johnson & Johnson	JNJ	367	0	0	633
JPMorgan Chase	JPM	512	0	0	488
Microsoft	MSFT	911	0	0	89
Pfizer	PFE	73	0	0	927
Procter & Gamble	PG	11	0	0	989
Walmart	WMT	0	0	0	1000

Tab. 3. Number of simulations where strategies recorded the highest annual appreciation in the shorter time interval, i.e. the earliest start date on January 3, 2012 and the latest end date on July 31, 2019.

As results presented in Tab. 2 and Tab. 3 indicate, the best results are usually achieved by MFI with other than recommended settings. To determine for which combination of parameters p and L we observed the highest annual appreciation we use a heat map. A demonstration for Apple in the longer time interval (the earliest start date on January 2, 2007 and the latest end date on July 31, 2019) is shown in Fig. 3. Each value represents the average annual appreciation for MFI with given values of p and L. The highest average appreciation (20.3 % p. a.), was achieved by MFI with $p = 5$ and $L = 33$. The combination that achieved the highest average annual appreciation was found for each company and the results are shown in Fig. 4 and Fig. 5.

The heatmap in Fig. 3 also reveals how stable the results are. Changes in L does not affect the results as much as the change in p. This was generally observed in the other obtained heatmaps and, also with regard to the definition of the MFI, it is an expected result. The results indicate that some "areas" show a higher average annual appreciation, while other "areas" show a lower appreciation. This was again observed for other companies. Finally, the heatmap demonstrates that low values of L may end in situation where no trade is made – the "area" of zeros in the lower left corner, and this "area" is adjacent to the "area" with high appreciation that is similar to buy-and-hold strategy as only several (or one) trade is made for a given combination of parameters.

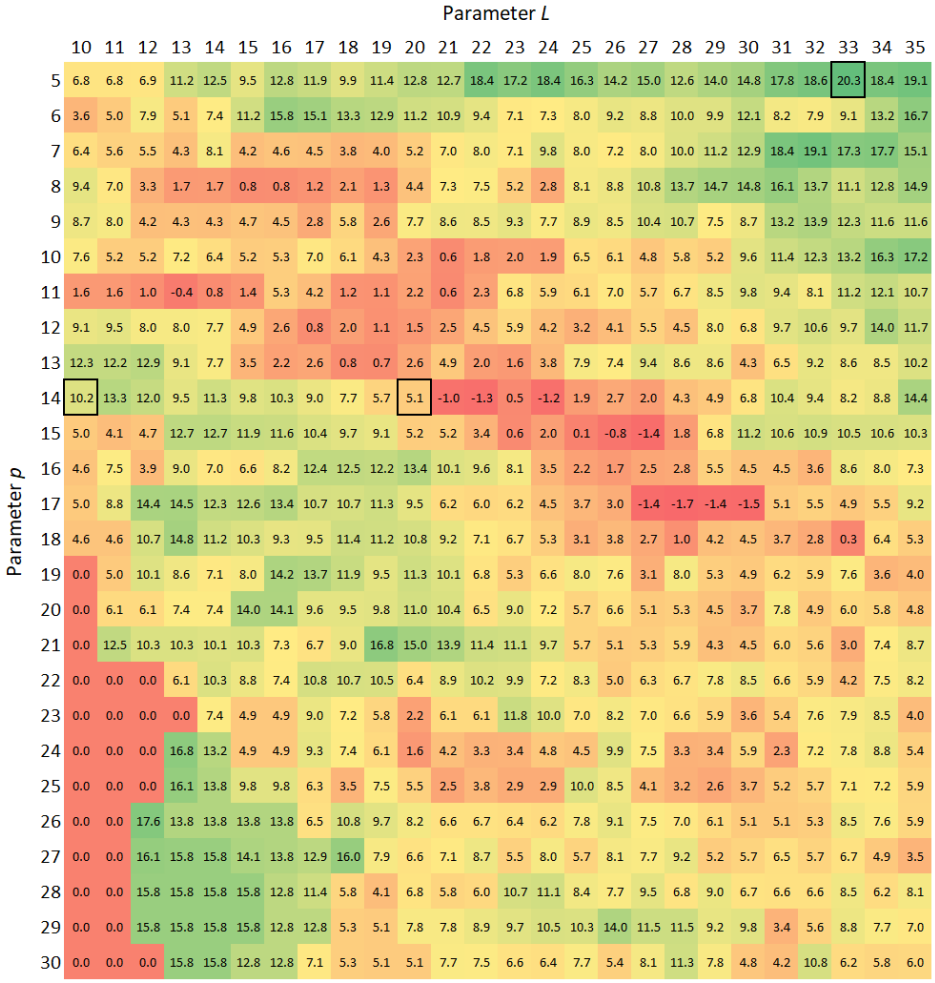

Fig. 3. Average annual percentage appreciation for MFI with each parameter combination for Apple in the longer time interval, i.e. the earliest start date on January 2, 2007 and the latest end date on July 31, 2019.

Fig. 4 and 5 contain boxplots of simulations for the buy-and-hold strategy, MFI with standard parameters ($p = 14$ and $L = 20$), MFI with parameters set to indicate truly oversold/overbought stock ($p = 14$ and $L = 10$), and MFI that achieved the highest annual appreciation (the second boxplot for each stock, the first parameter is p and the second parameter is L). MFI with optimum parameters usually has a higher annual appreciation than the buy-and-hold strategy. Nevertheless, there is no clear answer as to what parameter settings should be used in general, as results vary for each company and even for the longer and shorter time interval. A stronger conclusion can be made regarding the values of the parameters recommended in the literature ($p = 14$, $L = 20$, and $p = 14$, $L = 10$), because the results showed that a strategy based on them usually achieved the average annual appreciation lower than the simple buy-and-hold strategy, i.e. there is no special reason to use them.

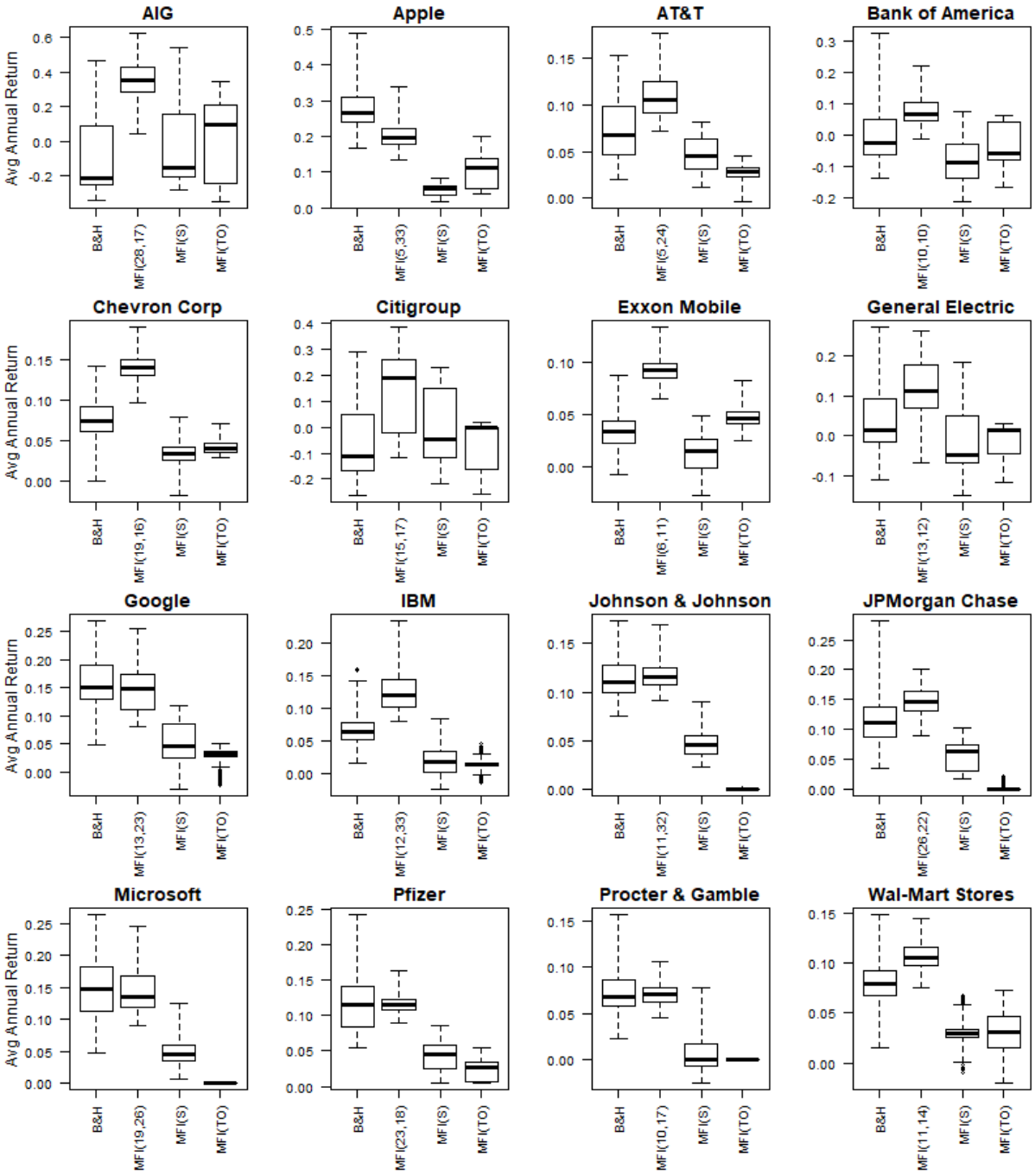

Fig. 4. Boxplots of the average annual appreciation for the buy-and-hold strategy, MFI with the highest annual appreciation, MFI with the standard parameters and MFI with the parameters set to indicate truly oversold/overbought stock (the longer time interval, i.e. the earliest start date on January 2, 2007 and the latest end date on July 31, 2019).

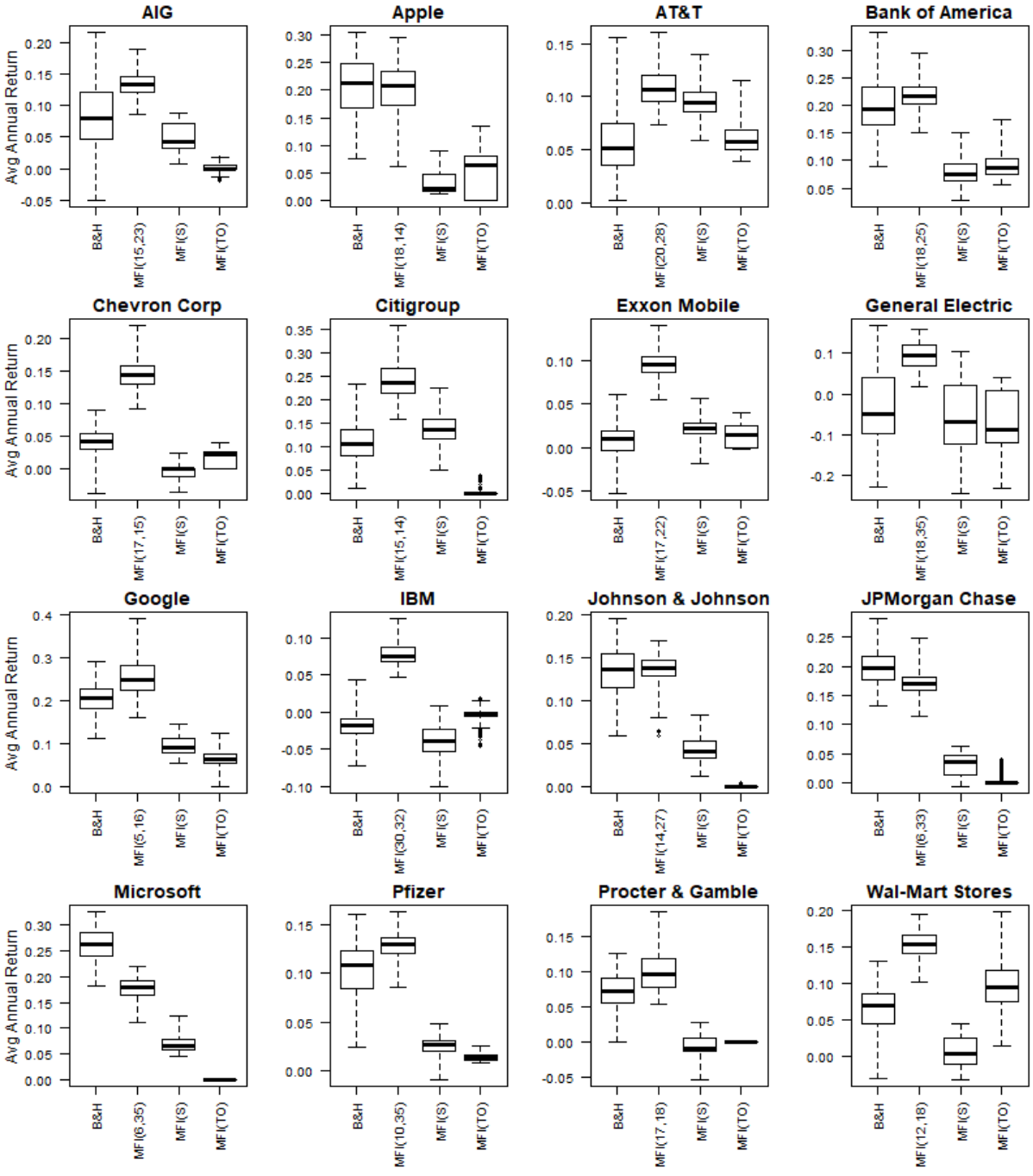

Fig. 5. Boxplots of the average annual appreciation for the buy-and-hold strategy, MFI with the highest annual appreciation, MFI with the standard parameters and MFI with the parameters set to indicate truly oversold/overbought stock (shorter time interval, i.e. the earliest start date on January 3, 2012 and the latest end date on July 31, 2019).

5 Discussion

Tab. 2 and Tab. 3 show that strategy based on MFI can yield higher annual appreciation than the buy-and-hold strategy; therefore, the use of the strategy based on MFI may be beneficial. This is in contrast to the results shown by Marek and Šedivá (2017) who showed that in most cases the buy-and-hold strategy yielded better results than a strategy based on optimized RSI or RSI with recommended parameters. Their results are not directly comparable to the results presented in this paper because they used day-to-day optimization of RSI; however, it suggests that MFI produces better results than RSI. This can be expected because MFI contains not only information about the close price but also about the high and low prices of the day and volume. To summarize this, the first question of this paper – whether the MFI, more than 30 years after its publication, can yield better results in the competition to the simple buy-and-hold strategy – can be answered rather positively.

The second question – whether a different setting of parameters p and L can lead to a higher capital appreciation – can also be answered positively. Tab. 2 and Tab. 3 showed that the two recommended MFI settings in the literature ($p = 14,\ L = 20$, and $p = 14,\ L = 10$) are overcome in all cases by other settings of parameters p and L. The only exception was recorded in shorter time interval for AT&T where MFI with standard parameters ($p = 14,\ L = 20$) achieved the best results in 17 (out of 1 000) simulations.

Based on the results presented in Fig. 4 and 5, we are unable to recommend one specific setting of parameters because we obtained different optimal settings for each company and each time interval. The recommendation is to optimize parameters for each company on historical data and use these optimized settings. As indicated in Fig. 3, small parameter changes do not cause radical change in the annual appreciation and the results can be considered robust. However, robustness was not an analysed issue in this paper and it would be necessary to analyse how often the parameters should be optimized and how this affects the profitability of a strategy based on MFI.

It should be also noted that several indicators are usually used to create automated trading system. MFI and RSI are very popular oscillators and based on our results and the results presented in Marek and Šedivá (2017) we recommend using MFI rather than RSI.

6 Conclusion

This paper studied Money Flow Index (MFI) and how different settings, other than those recommended in the literature, can affect the annual appreciation. For the comparison, we performed simulations in the randomized time interval with the start date of each simulation round generated between January 2, 2007 and December 31, 2009, and the end date generated between January 2, 2015 and July 31, 2019. This ensures that results are not affected by one particular time interval selection. All simulations were performed for the largest companies in the S&P 500 Index in 2006–2009. All results were also compared to the simple buy-and-hold strategy.

The results showed, that strategies based on MFI with the two recommended MFI settings in the literature ($p = 14,\ L = 20$, and $p = 14,\ L = 10$) were overcome by other settings of its parameters. We could not, however, set specific settings for these parameters, or some subset of settings, that could be generally recommended. The conclusion is that the parameters recommended in the literature are currently of no significant importance (because they do not

offer any additional advantage in trading) and that one should optimize the parameters for each stock before the start of trading.

The positive conclusion was that strategy based on MFI can overcome the simple buy-and-hold strategy for many stocks studied in this paper, and that it can offer an additional advantage to the trading.

To confirm the results of the paper, we performed simulations in the shorter time interval. The findings were the same, i.e., MFI with some parameters can be used to achieve higher appreciation than the buy-and-hold strategy, and it is not possible to recommend one specific p and L setting for all stocks in general.

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