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Optimal lengths of moving averages for the MACD oscillator for companies listed on the Warsaw Stock Exchange

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Abstract

The aim of the paper is to find optimal exponential moving averages for the main technical analysis oscillator MACD (Moving Average Convergence Divergence) which trigger buy and sell signals for companies from the WIG20 index, the mWIG40 and the sWIG80 index, listed on the Warsaw Stock Exchange. The analysis was conducted on the basis of data collected from 17 November 2000 to 31 December 2018, i.e. from the day when the WARSET system was introduced. The optimization was done with the method based on rates of return because they influence the final investment result.

It is the first research of this kind on the Polish financial market. It shows that each of the examined companies has its own lengths of moving averages which optimize rates of return, however, for some enterprises these values may be the same. Many research papers on technical analysis apply standard lengths for averages used in MACD. The authors of the present paper find out that investors should not follow them automatically, but rather look for optimal values for each market and each company. Such an opinion stands in sync with research literature which proves a varying efficiency of technical analysis tools, depending on the market development level, its transaction volume or its liquidity.

Keywords: technical analysis, MACD, moving average

JEL: G15, G17

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1 Introduction

The discussion of the possibilities of generating excess rates of returns with the use of technical analysis tools is the subject of many studies of results obtained on different markets conducted by various authors in the international literature on finance. This kind of research raises many controversies because if one assumes that technical analysis leads to results exceeding the risk premium, it automatically causes the rejection of the Fama (1970) efficient market theory, even in its weak form. The main technical analysis tool is the MACD oscillator, which was applied for the first time by Appel (1979). Its usage is based on the principle that forecasts of potential asset behaviour aimed at supporting investors in generating excess returns are created on the basis of historical asset price quotations. The application of the above mentioned oscillator requires the adequate choice of time spans for the difference between two exponentially weighted moving averages, as well as the time period for the exponential average which plays the role of the signal line. The difference obtained from averages calculated on close prices is called the MACD line, whereas the exponential average for the MACD line is called the signal line. This method is applied on financial markets in order to find buy and sell signals for assets, which are graphically represented by the intersection of these two lines. When the MACD oscillator crosses up from below its moving average, the market is interpreted as bullish and the buy signal is generated. If the MACD crosses down over its moving average, the sell signal appears. Both in financial markets practice and in the financial literature the typical settings of average lengths are: 12, 26, 9 (MACD (12, 26, 9)) days or weeks (Murphy 1999, p. 221).

The research presented in the financial literature is often conducted with the use of stock market indexes. The advantage of this paper is that every single company from three stock indexes on the Warsaw Stock Exchange was analyzed separately. It is a more useful attitude towards investments than making conclusions for indexes where the weights of the constituting companies do not have to be equal. Additionally, from the point of view of putting this research into practice on financial markets, if one has only results for indexes, even if this theoretically gives the possibility of generating higher rates of return than the risk-free interest rate, it would still be necessary to apply some derivative for which this index would play the role of an underlying asset. If one uses futures contracts, for example, the basis risk appears, which may cause the final result to be far away from the one indicated by the research.

Besides, the authors of the research on the application of the MACD oscillator are more often focused on checking if the results received with it are better than those conducted for the risk-free interest rate, instead of seeking optimal lengths of averages which should be used in order to get the best result possible for the chosen assets. Some of them assume certain standard time lengths for the moving averages. The research conducted by the authors of this study shows that there is nothing like standard time lengths for moving averages for all kinds of investments for which the transaction system based on the MACD oscillator is applied. Each of the examined companies has its own lengths of moving averages which optimize rates of return, although for some of them these values may be the same. According to the best knowledge of the authors of this paper such optimization has not been conducted for the Warsaw Stock Exchange companies before. The advantage of the paper is its complexity. The research comprises a large (140) number of companies from three market indexes: the WIG20 index, the mWIG40 index and the sWIG80 index.

2 Literature overview

In the Polish literature issues related to technical analysis are rare. Borowski (2014) describes the possibilities of applying various kinds of technical analysis oscillators on financial markets. Pruchnicka--Grabias (2018) uses a standard MACD to analyze the rates of return of the main pairs of world currencies. Comparing them with the buy and hold strategy indicates the possibility of making slightly higher profits when technical analysis is applied. The international literature, on the other hand, features many scientific papers which prove that technical analysis is useful on various markets. Nevertheless, the overall results of research on the usage of technical analysis oscillators are ambiguous and contradictory. There are some papers which discredit technical analysis as a prognostic tool, as well as papers showing that analyzed oscillators lead to higher rates of return than the assumed benchmarks. Research results in this area differ from each other depending on the chosen methodology, analyzed market or considered period of time. Among this fraction of the professional literature where the MACD is not regarded as a useful tool for making additional profits, Armour, Lofton and Oyenekan (2010, cited according to: Anghel 2015) stand out. The authors test stocks from the main Irish Stock Exchange index for the 20-year period and show that the strategy based on the standard MACD does not generate such attractive rates of return as the buy and hold approach. Chen et al. (2012) configured the MACD (12, 26, 9) applying a simple moving average and conducting the research on the main stock index of the Brazilian Stock Exchange (BOVESPA) for the period from January 1996 to January 2011. They conclude that one cannot obtain better results than for the buy and hold strategy. Besides, they did the research on other oscillators (such as, for instance, the moving average – the MA – or the Relative Strength Index – the RSI) and state that technical analysis has no predictive power. Thus, they prove that the Fama (1970) informational market efficiency in the weak form exists. Meissner, Alex and Nolte (2001) show that the standard MACD (12, 26, 9) does not provide good results compared to risk--free assets (Treasury bonds) or stocks from the analyzed NADAQ-100 index for a 10-year time period. The conclusion drawn from this research is that the classical MACD provides better results than the chosen benchmark only for about 32% of cases. Similar conclusions were drawn for 30 stocks from the DJIA index (Dow Jones Industrial Average). Moreover, the authors noticed that if they change the lengths of the applied averages, results do not improve significantly, however there exists a positive correlation between extending averages and the number of cases where the benchmark is exceeded. Biondo et al. (2013) study 5 chosen investment strategies comprising technical analysis oscillators (for example the MACD (12, 26, 9)) and a strategy based on randomness. The analysis was conducted for chosen stock indexes: FTSE-UK, FTSE-MIB, DAX, S&P500 for the period of 15–20 years. It covers a time span from the moment of the creation of each index to the end of the analyzed period. The authors emphasize that from time to time oscillators generate higher rates of return than the random strategy for short time spans. However, if one considers the use of such tools as well as the risk involved, one cannot say that technical analysis is more efficient than the random strategy constructed by the authors. Taking these research results into consideration it can be concluded that the existence of a standard MACD cannot be assumed. Instead, investors should choose MACD averages individually for every single company or index. This statement forms the foundation for the research presented in the present paper.

The second group of publications are those in which authors prove the superiority of technical analysis oscillators over the buy and hold strategy or any other method of holding money. From the point of view of this paper extremely important conclusions are presented in Erić, Andjelic and Redźepagić (2009), where the profitability of strategies based on the MACD oscillator was stressed. The authors also point out the necessity of optimization of the applied parameters, which increases the efficiency of investment. They conducted their research on stocks from the developing market in the Republic of Serbia. Results presented by Brock, Lakonishok and LeBaron (1992) indicate that higher rates of return crop up when different kinds of moving averages are applied than in the case of money held on the deposit market. The authors apply data from the Dow Jones index and for the examined period of 1897–1986. They additionally notice that buy signals are stronger than sell signals. Sullivan, Timmermann and White (1999) prove the usefulness of applying moving averages for the Dow Jones Industrial Average index for the period 1897–1986, which gives better results than the assumed benchmark. Anghel (2015) did the broad research based on stock markets from 75 countries from all over the world, which included 1336 companies examined from January 2001 to December 2012. The author says that in some cases it is possible to generate additional rates of return thanks to the MACD oscillator, which he additionally explains by the existence of informational inefficiencies in world markets. The paper suggests that the first step following the decision to use any oscillator (for example the MACD) should be to optimize the applied averages. Bodas-Sagi et al. (2009) notice that the most difficult activity in the use of technical analysis oscillators is the choice of appropriate parameters. Using self-chosen algorithms and data on quotations of the Dow Jones index for January 2000 – December 2005, they show the superiority of using MACD or RSI oscillators with suitably selected variables over oscillators with standard values. Chen et al. (2011) examine the usability of a few technical analysis oscillators (including the MACD) on the stock index from the Denmark Stock Market with data from July 1993 – June 2010. They come to the conclusion that oscillators have some predictive power. Kara, Boyacioglu and Baykan (2011) build models based, for example, on artificial neural networks using chosen technical analysis oscillators as input data (including the MACD) in order to forecast the behaviour of the stock index on the Istanbul Stock Exchange (ISE). It turned out that they can accurately anticipate stock price fluctuations. Hsu, Hsu and Kuan (2010) apply, among others, the moving averages on such indexes as: the S&P SmallCap600/Citigroup Growth Index (SP600SG), the Russell 2000 Index (RUT2000), the NSADAQ Composite Index (NASDAQ) and six emerging market indexes, as well as ETFs imitating chosen indexes. Authors prove that technical analysis generates higher rates of return than the risk premium. They also consider transaction costs, however, although these are lower for ETFs, if we take them into consideration, profits based on technical analysis are slightly lower than for the examined indexes. Ming-Ming and Siok-Hwa (2006) test moving averages using Asian market indexes (China, Thailand, Taiwan, Malaysia, Singapore, Hong Kong, Korea, Indonesia) between January 1988 and December 2003. Research results presented by authors suggest that technical analysis oscillators are worth applying. Wang and Kim (2018) point out that the MACD oscillator is a useful method of seeking buy and sell signals bringing up the example of a company chosen from the Shanghai Stock Exchange and analyzing the period between November 2015 and September 2017. Authors compare the results obtained when the standard version of the MACD was used against those achieved while applying a self-constructed MACD based on historical volatility. They state that the latter generates about 33% of effective cases, which gives a 12-percentage point better result than the former. Kulkarni and More (2014) choose five companies' quotations from the Bombay Stock Exchange (BSE) and show that the strategy based on the standard MACD leads to profit generation. Khatua (2016) utilizes the MACD and other chosen technical analysis indicators in order to anticipate the behaviour of stock prices of five selected companies from the CNX Nifty index at the National Stock Exchange (NSE). They conclude that such tools can be precious in making investment decisions. Stanković, Marković and Stojanović (2015) construct a model based on moving averages and RSI oscillators used as input data and apply it to the developing markets of Southern Europe. The authors deduce that technical analysis supports investment decision making and contributes to making excess rates of return compared to the buy and hold strategy. Additionally, the research presented by Methalchi, Marcucci and Chang (2012) includes the analysis of 16 European stock markets in 1990–2006 and also indicates the usability of moving averages in generating higher profits than the buy and hold strategy. They notice a relation between the efficiency of using moving averages and the size and capitalization of the market. Chong and Ng (2008) apply, among others, the MACD for the FT30 index on the London Stock Exchange (LSE) in a 60-year period. The authors state that it generates higher profits than the buy and hold strategy for the majority of analyzed cases. Wong, Manzur and Chew (2003) conduct an analysis based on companies from the Singapore Stock Exchange (SES) and apply the MACD and the RSI. They notice that the mentioned oscillators contribute to significant profits.

The third group of research papers on technical analysis indicates that it can be useful under some circumstances or when tools are appropriately selected or when linked with another investment method. Such an attitude is presented by Irwing and Park (2007), who conduct a broad analysis of studies concerning technical analysis published between 1960 and 2003. The authors say that technical analysis indicators are valuable only on currency markets, whereas they are worthless on stock markets. Moreover, they conclude that in the case of the MACD oscillator it is crucial to choose suitable lengths of moving averages without automatically relying on standardized parameters. Neely et al. (2014) associate the efficiency of technical analysis oscillators with the use of macroeconomic variables. According to the authors, such a strategy leads to the improvement of investment results. Zoicaş-Ienciu (2015) utilizes moving averages on the Bucharest Stock Exchange (BSE) and concludes that the success of various methods of technical analysis depends on the way in which they are used and the research results are reliant on the applied method. In this way the author explains the contradiction between different research results reported in scientific papers. Taylor (2014) conducts the research for 1928–2012 on companies from the DJIA index and shows that results vary depending on the time period. He also demonstrates that the efficiency of technical analysis tools depends on market conditions in which it is applied, such as liquidity, financial stability or the existence of possibilities of short selling. Similar conclusions, i.e. that the efficiency of strategies based on technical analysis depends on the market where it was used (developed or developing) derive from the paper written by Fifield, Power and Sinclair (2005). Authors conduct their research on 11 European stock markets in January 1991–December 2000 and state that these are developing markets on which the Fama informational efficiency (1970) does not exist and thus on which technical analysis oscillators are useful. This scheme was not confirmed for developed markets. Rosillo, Fuente and Brugos (2013) analyze companies from the Spanish stock exchange using the MACD and other technical analysis oscillators. They come to the conclusion that results depend both on the examined company and on the indicator applied. In turn, McKenzie (2014) does the research on 17 developing markets for the period between January 1986 and September 2003 with the results suggesting that technical analysis is helpful on stock markets and generates high rates of return, however, their range depends both on market conditions and transaction volume. Similar results are put forward by Pauwels et al. (2011), who check the efficiency of technical analysis methods on 34 developing markets. Only four of them turn out to be beneficial. They emphasize that technical analysis is generally useless if one compares it to the buy and hold strategy, however, they signal its marginally higher usefulness during the crisis period. In turn, Todea, Zoicaş-Ienciu and Filip (2009) and Todea, Ulici and Silaghi (2009) show that profits deriving from the usage of moving averages cannot be treated as a given, because they appear only from time to time. In other words, when the market efficiency changes, the advantages of technical analysis oscillators keep appearing and disappearing.

The literature on the MACD oscillator usage can also divided into two following parts. The first one refers to the traditional approach and authors use the MACD for standard values of averages, i.e. (12, 26, 9). The second one encourages to put other lengths of moving averages into practice. For example, Kaufman (2013, p. 382) recommends to apply the MACD (20, 40, 9), however, together with the weights of 0,0243 and 0,0476 for the 20-session and 40-session averages, respectively. In turn, the creator of the MACD oscillator – Appel (2005) proposes to use the MACD (19, 39, 9) oscillator in the case of the NASDAQ Composite index. Apirine (2017) considers using the MACD oscillator for daily data and the MACD oscillator for weekly data, which creates a superposition of two oscillators, i.e. the W&D MACD (60, 130, 12, 26). The W&D MACD fluctuates around zero and the daily MACD oscillates over or under the W&D MACD. Other lengths of W&D MACD oscillators can be applied depending on the investor's transaction style and investment purposes. Seykota (1991) also denies the usability of the MACD (12, 26, 9), after having conducted tests with the S&P500 index. Similarly, Du Plessis (2012) examines the usefulness of the standard MACD in comparison with the buy and hold strategy for the stock market on the Johannesburg Stock Exchange (JSE) and concludes that better results can be achieved when the latter is applied. Predipbhai (2013) conducts research based on the big companies index (the CNX Nifty index from the National Stock Exchange of India) and compares results obtained with the standard MACD based on exponential averages with those realized with the standard MACD based on simple moving averages and shows that higher rates of return can be generated in the first case. In the light of the above mentioned research papers, the authors of this paper propose the choice of optimal lengths of exponential averages for companies quoted on the Warsaw Stock Exchange.

3 Methodology

The MACD (N_1, N_2) oscillator is the difference of two moving averages of length N_1 and N_2, calculated for closing prices and exponentially weighed:

$$MACD(N_1, N_2) = EMA(C, N_1, E) - EMA(C, N_2, E)$$

Notation $EMA(C, N_1, E)$ represents the N_1 period exponentially weighted moving average of closing prices (C).

When the MACD (N_1, N_2) crosses over its N_3 period exponentially weighted moving average, a buy signal is generated:

$$MACD(N_1, N_2) > EMA(MACD(N_1, N_2), N_3, E)$$

The sales signal is generated when the opposite condition occurs:

$$MACD(N_1, N_2) < EMA\left(MACD(N_1, N_2), N_3, E\right)$$

In such a way, a transaction system was constructed based on the intersection of the MACD oscillator by its moving average, where the variables are the lengths of the three moving averages: N_1, N_2 and N_3.

The study assumes that the variables N_1, N_2 and N_3 may vary from 3 to 50 sessions with a step of 1 session. In particular, it may turn out that two or even three variables are equal. The research focused on companies listed on the Warsaw Stock Exchange (as at 31 December 2018), included in the following three indexes: the WIG20, the mWIG40 and the sWIG80, i.e. a total of 140 companies. The analysis was applied to four groups: the G_{20} – companies from the WIG20 index, the G_{40} – companies from the mWIG40 index, the G_{80} – companies from the sWIG80 index, and the G_{140} – all analyzed companies, e.g. companies belonging to three indexes (WIG20, mWIG40 and sWIG80). The research covered the period from 17 November 2000 to 31 December 2018. The starting date was set at the date of the introduction of the WARSET system allowing the continuous listing on the Warsaw Stock Exchange. Considering companies whose date of the first listing (X) fell after 17 November 2000, the research period included sessions in the range from X to 31 December 2018 (Tables 2 and 3 in the Appendix). The company's rates of return were adjusted to the paid dividends, based on information from the Notoria.pl website. 110,592 tests were run involving three variables N_1, N_2 and N_3 for each equity. For each of the company, 10 sets of moving average lengths (N_1, N_2, N_3), generating ten highest rates of return in the examined time horizon, were used in the analysis. Thus, the G_1 group consisted of 200, the G_2 group of 400, the G_3 group of 800, and the G_{140} group of 1,400 sets of (N_1, N_2, N_3).

Research hypotheses were defined as follows:

Hypothesis 1

In the case of 140 companies included in the three price indexes: the WIG20, the mWIG40 and the sWIG80, the transaction system based on buy and sell signals generated by the MACD oscillator results in the highest rates of return when the several session moving average has been used for the construction of the MACD oscillator.

Hypothesis 2

In the case of 140 companies included in the three price indexes: the WIG20, the mWIG40 and the sWIG80, among the top 10 transaction results for each of the companies it is often the same average lengths that form the MACD oscillator, but in a different order.

Hypothesis 3

In the case of 140 companies included in the three price indexes: the WIG20, the mWIG40 and the sWIG80, the lengths of moving averages optimizing the transaction system based on buy and sell signals generated by the MACD oscillator, are in major part odd numbers.

4 Results

4.1 Analysis of the length of moving averages forming the MACD oscillator

All companies (G_{140})

Analyzing the companies included in all three (G_{140}) indexes and all the (N_1, N_2, N_3) averages one can conclude that the transaction system was optimized mainly by short moving averages. The share of the 3-session moving average was equal to 16.50%, ahead of the 4- and 5-session moving average, with the shares of: 9.33% and 8.36%, respectively (Table 1, Appendix). Attention should be also drawn to the growing share of moving averages with lengths from 23 to 29 sessions, with a slight portion of moving averages with lengths greater than 30 sessions. Similar conclusion can be drawn with respect to the length of the moving average N_1. In the case of the second moving average (N_2), an average of 5 sessions (10.07%) was the most frequently recorded, ahead of the moving averages of 4 (8.50%) and 6 sessions (6.36%). The share of the moving averages ranging from 23 to 30 sessions and from 45 to 50 sessions is also clearly visible, with a small share of the moving averages of 31–36 sessions. In the case of the third moving average (N_3), the length of 3 sessions dominated (21.36%), ahead of the 4- and 5-session moving averages (their share amounted to 9.50% and 8.50%, respectively).

Companies included in the WIG20 (G_{20}) index

In the group of companies included in the WIG20 index and the group of all moving averages (N_1, N_2 and N_3), there were three moving average lengths that dominated the set, i.e. the 3-session (10.17%), the 10-session (7.83%) and the 7-session (7.17%) span. There were other lengths of moving averages, whose participation was greater than or equal to 5%, and these were the 8-session (5.17%) and 11-session (5.00%) spans. It is worth noting the low presence of moving averages with lengths from 31 to 37 sessions and a growing share of moving averages with lengths from 47 to 50 sessions. Table 2, in the Appendix, includes the lengths of moving averages that maximized profits in a given transaction system (the remaining 9 sets, for each of the securities, were not included). In the group of moving averages N_1, the transaction system was most often optimized by the 10-session moving average (8.50%), ahead of the 3-session moving average (6.00%) and moving averages with the lengths of 8, 11, 23 and 24 sessions (the share of each of these averages was equal to 5%). Moving average lengths from 30 to 40 sessions were not recorded.

In the group of moving averages N_2, the most frequent length of the moving averages were 3 (12.50%), 7 (9.50%) and 10 (8.50%) sessions. There were no moving averages whose length was equal to 15 or 16 sessions and none whose length came from the range of 34 to 46 sessions either. In turn, the share of the 50-session moving average was 4.50% and was the same as the share of the 8-session moving average. In the case of the moving average N_3, the dominance of the 3-session moving average (12%) was visible, ahead of the 7-session (8.50%) and 10-session (6.50%) moving average. The local maximum of the share of a moving average length near 21 sessions (6%) deserves attention.

Companies included in the mWIG40 (G_{40}) index

In the group of companies belonging to the mWIG40 index and the group of all moving averages (N_1, N_2, N_3), the following averages dominated: the 3-session (18.50%), the 4-session (10.33%) and the 5-session (7.75%) average. With a steady decline in the shares of individual moving averages, resembling the cup pattern from technical analysis, the local extreme is found in the 9-session moving average (5.42%) and the 29-session moving average (3.50%). The share of moving averages with lengths longer than 30 sessions is small. Table 2, in the Appendix, includes lengths of moving averages that maximized profit in a given transaction system (the remaining 9 sets, for each of the securities, were not included). In the group of moving averages N_1, the following lengths of moving averages dominated: 3 (25.5%), 4 (12.50%) and 9 (6.00%) sessions. The share of moving averages of more than 30 sessions should be considered negligible. The most frequently recorded moving averages of N_2 were the moving averages with the following lengths: 5 (10.25%), 4 (9.00%) and 6 (6.75%) sessions. The length of moving averages, whose share exceeded 5%, in addition to the previously mentioned ones, was: 9 (6.50%), 3 (5.00%) and 7 (5.00%) sessions. The local extremum is also noticeable for the moving average of 29 (3.50%) sessions. In the N_3 moving average group, there is a clear dominance of the moving average of 3 sessions (25.00%), ahead of the 4- and 5-session averages (respectively 9.50% and 8.25%).

Companies included in the sWIG80 (G_{80}) index

In the group of companies belonging to the sWIG80 index and the group of all moving averages (N_1, N_2, N_3), the most frequent moving averages were: the 3-session (17.08%), the 4-session (10.50%) and the 5-session (9.67%) average. The analysis of the frequency distribution of moving averages proves a clear downward trend, down to the moving average of 22 sessions (0.46%) and then slightly increasing, up to the moving average of 29 sessions (3.33%). Moving average lengths greater than 30 were reported on an occasional basis. Table 3 in the Appendix presents the lengths of moving averages that maximized profit in a given transaction system (the remaining 9 sets, for each of the securities, were not included). In the group of moving averages N_1, the dominance of short moving averages is noticeable, with the largest shares for the 3- (24.50%), 4- (10.63%) and 5-session (8.25%) average. No moving averages with lengths greater than 30 sessions were observed. The lengths of the second moving average N_2, most often optimizing the transaction system, were 5 (11.00%), 4 (9.63%) and 6 (7.13%) sessions. Also noteworthy are the moving averages with a length of 29 (5.79%), 27 (3.75%) and 30 (3.75%) sessions. In the group of the moving averages N_3, the dominance of short-term moving averages is remarkable, with 3- (21.88%), 4- (11.25%) and 5-session (9.75%) averages as the most conspicuous. No moving averages longer than 32 session were observed.

4.2 Sets of moving averages that maximize returns (similar sets)

While analyzing the length of moving averages that maximized rates of return for individual shares, it was observed that in many cases among the top 10 transaction results the same lengths of moving averages can be identified, but appearing in a different order, e.g.: (10, 13, 8), (8, 10, 13) or (8, 13, 10). None of the studies known to authors, had investigated this type of dependence, therefore an attempt was made to analyze the phenomenon. Due to the fact that in some cases the lengths of moving averages optimizing the transaction system differ from one another by one session (e.g. (10, 13, 8) and (9, 13, 8) etc.), the following average sets (N_1, N_2, N_3) were taken into account:

1. The lengths of moving averages N_1, N_2, N_3, may occur in a different order, e.g. (N_1, N_2, N_3) or (N_2, N_1, N_3).

2. One of the moving averages included in the set of three lengths may be higher or lower than the same average in another set of three moving averages, but not by more than 1, i.e. (N_1, N_2, N_3) and (N_1, $N_2 + 1$, N_3).

The three moving averages that implement both of the above conditions can e.g. take the form of (N_1, N_2, N_3) and (N_3, $N_2 + 1$, N_1), (N_1, $N_2 - 1$, N_3), to give an example. Later in this paper, such sets will be called "similar sets".

For each security, the percentage of similar sets was determined among ten out of all sets optimizing the transaction system. The percentage of similar sets, larger or equal to 50%, occurred for 77.86% of all sets in the group of all analyzed companies. The percentage of similar sets, larger or equal to 60%, 70%, 80% and 90% in the same group of companies was equal to 67.14%, 55.71%, 42.14% and 27.14%, respectively. For companies included in the analyzed indexes, the results are presented in Table 1. The percentage of similar sets is the highest in the case of the WIG20 index companies, ahead of the sWIG80 and mWIG40 index components.

Table 1

The percentage of similar sets among all sets of moving averages optimizing the transaction systems (in %)

	All companies	**Components of WIG20**	**Components of mWIG40**	**Components of sWIG80**
≥ 50%	77.86	80.00	72.50	80.00
≥ 60%	67.14	80.00	60.00	67.50
≥ 70%	55.71	65.00	47.50	57.50
≥ 80%	42.14	55.00	37.50	41.25
≥ 90%	27.14	35.00	22.50	27.50

Source: own calculation.

Such a high percentage of similar sets makes it possible to formulate the conclusion that in many cases the permutation of the length of moving averages, with a possible change in the length of one of them by one session, leads to similar transaction results. This is a feature that distinguishes the MACD-based transaction system from the transaction system based on the intersection of moving averages. The occurrence of similar sets among the above chosen ten sets optimizing the transaction system may be considered as a proof of its stability – this remark is particularly valid for the change of one of the lengths of the moving averages by one session. Changing the length of the moving averages by one leads in this case to similar rates of return for the analyzed transaction systems.

4.3 Parity and oddness of moving average lengths that maximize returns

Based on the conducted research, it was possible to determine whether the length of moving averages that optimize the transaction system, is an even or an odd number – these data are presented in Table 2. In most cases, except for the N_2 moving averages, calculated for the mWIG40 index components, they proved to be odd numbers. The highest percentage of odd numbers was observed in the case of the moving average N_3 and companies belonging to the mWIG40 index (61.00%). In all the analyzed groups of companies (G_{20}, G_{40}, G_{80} and G_{140}) the percentage of moving averages with odd lengths N_3 was the largest.

Table 2

Frequencies of occurrence of even and odd lengths of moving averages in the analyzed groups of companies (in %)

	All companies				Components of WIG20				Components of mWIG40				Components of sWIG80			
	All lenghts	First moving average	Second moving average	Third moving average	All lenghts	First moving average	Second moving average	Third moving average	All lenghts	First moving average	Second moving average	Third moving average	All lenghts	First moving average	Second moving average	Third moving average
Even	43.45	42.07	47.86	40.43	46.00	47.00	46.50	44.50	44.08	42.50	50.75	39.00	42.50	40.63	46.75	40.13
Odd	56.55	57.93	52.14	59.57	54.00	53.00	53.50	55.50	55.92	57.50	49.25	61.00	57.50	59.38	53.25	59.88

Source: own calculations.

The analysis of the parity and odd parity of analyzed moving averages (e.g. EEO means that the first average (N_1) is even (E), the second (N_2) is even (E) and the third (N_3) remains odd (O)) proves that in the group of all companies, the OEO scheme was the one which optimized the transaction system the most often (17% of all moving average systems). The same regularity was true in the group of companies belonging to the sWIG80 index (17.88%). On the other hand, in the group of companies included in the WIG20 index and the mWIG40 index, the system of moving averages most often optimizing the transaction system was the EOO and OOO scheme, respectively. The least preferred schemes of moving averages, in the group of all companies and companies belonging to the WIG20, the mWIG40 and the sWIG80 indexes were respectively: EEE, EEO, EEE and EEE. The MACD transaction system commonly used in technical analysis is the (12, 26, 9) scheme of moving averages, i.e. the EEO type.

Table 3

Frequency of parity and oddness schemes of moving averages in analyzed groups of shares (in %)

	Parity and oddness schemes of moving averages							
	EEE	**EEO**	**OEE**	**OEO**	**EOE**	**EOO**	**OOE**	**OOO**
All companies	7.00	11.00	12.86	17.00	9.07	15.00	11.50	16.57
WIG20	**10.50**	*9.50*	*11.50*	*15.00*	**10.50**	**16.50**	12.00	*14.50*
mWIG40	7.50	**13.00**	**14.00**	16.25	*7.75*	*14.25*	*9.75*	**17.50**
sWIG80	*5.88*	10.38	12.63	**17.88**	9.38	15.00	**12.25**	16.63

Note: bold marked the highest values, and italic – the lowest.

Source: own calculations.

5 Conclusions

The paper presents the analysis of the efficiency of the transaction system based on the intersection of the MACD (N_1, N_2) oscillator and its moving average N_3 as a function of the length of averages: N_1, N_2 and N_3 (which is recorded in short as MACD (N_1, N_2, N_3)). The majority of scientific research related to technical analysis uses the approach where following moving averages are used: $N_1 = 12$, $N_2 = 26$ and $N_3 = 9$. Meanwhile, our analysis proved that for each of the financial instruments, a set of three variable lengths (N_1, N_2, N_3) optimizing the transaction system represents an individual feature of this instrument. Therefore, the automatic use of the MACD (12,26) and its moving average $N_3 = 9$ (which can be shortened as MACD (12, 26, 9)) to all analyzed instruments seems to be unjustified or to constitute at best some kind of simplification of the conducted analysis and does not guarantee the highest possible rate of return possible to achieve with the MACD (N_1, N_2, N_3) transaction system.

The main limitation of the study is the inequality of time horizons in which it was conducted for different companies. The obtained results clearly indicate that on the Polish capital market the averages that optimize the tested transaction system are most often a few session long. Therefore, investors using the MACD (12, 26, 9) oscillator in their analyses should rather use the MACD (N_1, N_2, N_3) oscillator to increase the efficiency of buy and sell signals it generates, where N_1, N_2 and N_3 belong to the range from 3 to 50 (investors with longer investment horizons can use a wider range of parameters, for example from 3 to 100 or even to 200 sessions). Moreover, it has been proved that the selection of odd lengths of moving averages to the MACD oscillator increases the chance of obtaining higher rates of return than the selection of moving averages of even lengths. The highest rates of return were obtained for the odd-even-odd (OEO) combinations of moving averages. Investors making their investment decisions on the basis of signals generated by the MACD oscillator and its moving averages should determine for each of the analyzed assets the length of moving averages N_1, N_2 and N_3, optimizing the indication of this system. However, if they do not allow such options, then it is advisable to remember that on the Polish capital market the lengths of moving averages N_1, N_2 and N_3 tend to be as short as possible, with numbers N_1 and N_3 being odd numbers and N_2 even numbers.

An important conclusion drawn from the conducted analyses is the emergence of similar sets, in which the replacement of the order of the lengths of moving averages N_1, N_2, N_3 in the transaction system often leads to the same or similar rates of return. This issue had not been previously discussed in the literature, either international or national (focusing on the Polish market), and should also be analyzed on capital markets in other countries, as well as in other segments of the financial market such as currency and commodities.

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Appendix

Table 1
Frequencies of moving averages (N_1, N_2, N_3) in the analyzed groups of companies (in %)

Length of moving average	Group G140				Group G20				Group G40				Group G80			
	All moving average	Moving average N_1	Moving average N_2	Moving average N_3	All moving average	Moving average N_1	Moving average N_2	Moving average N_3	All moving average	Moving average N_1	Moving average N_2	Moving average N_3	All moving average	Moving average N_1	Moving average N_2	Moving average N_3
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	16.50	22.14	6.00	21.36	10.1	6.00	12.50	12.00	18.50	25.50	5.00	25.00	17.08	24.50	4.88	21.88
4	9.33	10.00	8.50	9.50	2.67	2.50	3.00	2.50	10.33	12.50	9.00	9.50	10.50	10.63	9.63	11.25
5	8.36	6.50	10.07	8.50	4.33	3.00	6.00	4.00	7.75	4.75	10.25	8.25	9.67	8.25	11.00	9.75
6	5.60	5.36	6.36	5.07	2.17	1.00	2.50	3.00	5.00	4.00	6.75	4.25	6.75	7.13	7.13	6.00
7	5.33	4.86	5.86	5.29	7.17	3.50	9.50	8.50	4.08	3.00	5.00	4.25	5.50	6.13	5.38	5.00
8	3.60	3.71	3.64	3.43	5.17	5.00	5.00	5.50	3.58	4.50	3.75	2.50	3.21	3.00	3.25	3.38
9	4.33	4.07	5.14	3.79	3.00	2.00	3.50	3.50	5.42	6.00	6.50	3.75	4.13	3.63	4.88	3.88
10	3.71	3.43	4.00	3.71	7.83	8.50	8.50	6.50	2.67	3.00	2.25	2.75	3.21	2.38	3.75	3.50
11	2.90	3.00	2.86	2.86	5.00	5.00	5.50	4.50	2.50	3.25	2.00	2.25	2.58	2.38	2.63	2.75
12	2.76	3.14	2.71	2.43	4.17	3.50	5.00	4.00	2.42	3.50	1.75	2.00	2.58	2.88	2.63	2.25
13	2.17	2.21	2.43	1.86	2.17	3.00	2.00	1.50	2.42	2.25	2.75	2.25	2.04	2.00	2.38	1.75
14	2.14	2.21	2.21	2.00	3.00	4.50	2.50	2.00	2.17	1.50	2.75	2.25	1.92	2.00	1.88	1.88
15	1.64	1.64	1.64	1.64	1.50	2.50	0.00	2.00	1.17	1.00	1.50	1.00	1.92	1.75	2.13	1.88
16	1.76	1.64	2.00	1.64	1.67	4.00	0.00	1.00	1.42	0.50	2.25	1.50	1.96	1.63	2.38	1.88
17	1.62	1.57	1.93	1.36	1.83	2.50	1.50	1.50	0.92	0.25	1.50	1.00	1.92	2.00	2.25	1.50
18	1.76	1.14	2.14	2.00	1.83	0.50	1.50	3.50	1.67	0.75	2.25	2.00	1.79	1.50	2.25	1.63
19	1.60	1.43	1.71	1.64	1.67	2.00	0.50	2.50	1.75	1.25	2.25	1.75	1.50	1.38	1.75	1.38
20	1.64	1.57	1.71	1.64	3.00	1.00	3.50	4.50	1.83	2.00	2.00	1.50	1.21	1.50	1.13	1.00
21	1.86	1.64	1.57	2.36	4.50	4.00	3.50	6.00	2.08	2.00	1.75	2.50	1.08	0.88	1.00	1.38
22	1.07	1.00	1.14	1.07	2.33	2.50	2.00	2.50	1.67	1.50	2.25	1.25	0.46	0.38	0.38	0.63
23	1.64	1.93	1.57	1.43	2.50	5.00	0.50	2.00	1.25	1.75	1.00	1.00	1.63	1.25	2.13	1.50
24	1.48	1.79	1.36	1.29	2.83	5.00	1.00	2.50	2.00	2.00	2.50	1.50	0.88	0.88	0.88	0.88
25	1.76	2.07	1.64	1.57	2.67	4.00	2.50	1.50	1.42	2.00	0.75	1.50	1.71	1.63	1.88	1.63
26	1.81	1.79	2.29	1.36	0.83	1.00	1.50	0.00	1.33	0.75	2.00	1.25	2.29	2.50	2.63	1.75
27	2.48	2.14	3.00	2.29	2.00	4.00	0.50	1.50	1.92	1.25	2.75	1.75	2.88	2.13	3.75	2.75
28	2.17	2.50	2.14	1.86	2.50	4.00	2.00	1.50	1.75	1.50	2.00	1.75	2.29	2.63	2.25	2.00
29	2.95	1.71	4.57	2.57	1.33	1.50	2.00	0.50	3.00	2.25	3.50	3.25	3.33	1.50	5.75	2.75
30	1.83	1.14	3.07	1.29	0.83	0.50	2.00	0.00	1.42	0.75	2.25	1.25	2.29	1.50	3.75	1.63
31	0.12	0.00	0.36	0.00	0.17	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.50	0.00

Table 1, cont'd

Length of moving average	Group G140				Group G20				Group G40				Group G80			
	All moving average	Moving average N_1	Moving average N_2	Moving average N_3	All moving average	Moving average N_1	Moving average N_2	Moving average N_3	All moving average	Moving average N_1	Moving average N_2	Moving average N_3	All moving average	Moving average N_1	Moving average N_2	Moving average N_3
32	0.55	0.29	1.00	0.36	0.17	0.00	0.50	0.00	0.42	0.75	0.00	0.50	0.71	0.13	1.63	0.38
33	0.31	0.14	0.64	0.14	0.17	0.00	0.50	0.00	0.25	0.50	0.00	0.25	0.38	0.00	1.00	0.13
34	0.07	0.00	0.07	0.14	0.17	0.00	0.00	0.50	0.17	0.00	0.25	0.25	0.00	0.00	0.00	0.00
35	0.17	0.00	0.29	0.21	0.17	0.00	0.00	0.50	0.50	0.00	1.00	0.50	0.00	0.00	0.00	0.00
36	0.17	0.14	0.07	0.29	0.17	0.00	0.00	0.50	0.42	0.50	0.25	0.50	0.04	0.00	0.00	0.13
37	0.05	0.07	0.00	0.07	0.00	0.00	0.00	0.00	0.17	0.25	0.00	0.25	0.00	0.00	0.00	0.00
38	0.29	0.14	0.36	0.36	0.33	0.00	0.00	1.00	0.83	0.50	1.25	0.75	0.00	0.00	0.00	0.00
39	0.24	0.07	0.29	0.36	0.33	0.00	0.00	1.00	0.67	0.25	1.00	0.75	0.00	0.00	0.00	0.00
40	0.29	0.07	0.43	0.36	0.50	0.00	0.00	1.50	0.75	0.25	1.50	0.50	0.00	0.00	0.00	0.00
41	0.21	0.07	0.29	0.29	0.50	0.50	0.00	1.00	0.50	0.00	1.00	0.50	0.00	0.00	0.00	0.00
42	0.21	0.21	0.29	0.14	0.17	0.50	0.00	0.00	0.67	0.50	1.00	0.50	0.00	0.00	0.00	0.00
43	0.17	0.36	0.00	0.14	0.83	1.50	0.00	1.00	0.17	0.50	0.00	0.00	0.00	0.00	0.00	0.00
44	0.14	0.36	0.00	0.07	0.67	1.50	0.00	0.50	0.17	0.50	0.00	0.00	0.00	0.00	0.00	0.00
45	0.10	0.14	0.14	0.00	0.33	1.00	0.00	0.00	0.08	0.00	0.25	0.00	0.04	0.00	0.13	0.00
46	0.05	0.07	0.07	0.00	0.17	0.50	0.00	0.00	0.08	0.00	0.25	0.00	0.00	0.00	0.00	0.00
47	0.12	0.07	0.21	0.07	0.50	0.50	0.50	0.50	0.08	0.00	0.25	0.00	0.04	0.00	0.13	0.00
48	0.26	0.21	0.36	0.21	1.33	1.00	1.50	1.50	0.25	0.25	0.50	0.00	0.00	0.00	0.00	0.00
49	0.29	0.21	0.64	0.00	1.17	1.50	2.00	0.00	0.08	0.00	0.25	0.00	0.17	0.00	0.50	0.00
50	0.40	0.00	1.21	0.00	1.50	0.00	4.50	0.00	0.33	0.00	1.00	0.00	0.17	0.00	0.50	0.00

Source: own calculations.

Table 2
The length of the three moving averages that maximize the transaction system in the case of companies included in the WIG20 and mWIG40 indexes

Number	Company (WIG20)	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3	Number	Company (mWIG40)	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3
1	ALIOR	21.09.2006	12	11	10	1	11BIT STUDIO	28.10.2010	39	40	39
2	CCC	02.12.2004	10	12	8	2	AMICA	08.09.1997	3	5	3
3	CD PROJEKT	02.08.1994	12	17	8	3	AMREST	27.04.2005	9	7	9
4	CYFROWY POLSAT	06.05.2008	25	14	7	4	ASSECOPOL	02.06.1998	19	25	25
5	ENERGA	11.12.2013	25	14	7	5	BENEFIT	21.04.2011	3	3	3
6	EUROCASH	04.02.2005	3	8	15	6	BOGDANKA	25.06.2009	7	8	6
7	JSW	06.07.2011	10	27	40	7	BORYSZEW	20.05.1996	43	48	5
8	KGHM	30.01.1996	24	29	20	8	BUDIMEX	25.05.1995	3	7	3
9	LOTOS	09.09.2005	4	5	4	9	CIECH	10.02.2005	4	42	3
10	LPP	16.05.2001	7	8	5	10	CIGAMES	30.11.2007	3	11	4
11	MBANK	06.10.1992	21	26	18	11	COMARCH	10.03.1999	4	42	3
12	ORANGE	18.11.1998	47	49	43	12	DINOPOL	19.04.2017	9	6	4
13	PEKAO	30.06.1998	8	3	3	13	ECHO	05.03.1996	4	23	19
14	PGE	06.11.2009	20	3	29	14	ENEA	17.11.2008	3	4	3
15	PGNIG	23.09.2005	5	3	3	15	FAMUR	04.08.2006	3	4	3
16	PKN ORLEN	26.11.1999	18	3	3	16	FORTE	24.07.1996	3	8	3
17	PKO BP	10.11.2004	14	10	9	17	GPW	09.11.2010	9	24	19
18	PZU	12.05.2010	15	10	15	18	GRUPA AZOTY	30.06.2008	25	9	23
19	SANTANDER BANK POLSKA	22.06.1993	8	7	24	19	GTC	06.05.2004	23	3	12
20	TAURON	30.06.2010	16	9	9	20	HANDLOWY	30.06.1997	13	29	5
						21	INGBS	25.01.1994	3	4	3
						22	INTERCARS	26.05.2004	20	28	6
						23	KERNEL	23.11.2007	3	7	3
						24	KĘTY	30.01.1996	18	4	12
						25	KRUK	10.05.2011	23	30	30
						26	LCCORP	20.06.2007	13	18	6
						27	LIVECHAT	11.04.2014	11	7	15
						28	MABION	10.08.2010	3	8	8

Table 2, cont'd

Number	Company (WIG20)	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3	Number	Company (mWIG40)	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3
						29	MILLEN-NIUM	13.08.1992	3	13	10
						30	ORBIS	20.11.1997	3	6	3
						31	PFLEIDER	06.05.1997	3	7	3
						32	PKP CARGO	30.10.2013	24	21	16
						33	PLAY	27.07.2017	4	4	3
						34	PLAYWAY	19.10.2016	5	19	3
						35	POLIMEX	15.10.1997	9	14	5
						36	SANOK	16.01.1997	5	27	26
						37	STAL-PRODUKT	06.08.1997	5	8	3
						38	TRAKCJA	01.04.2008	28	35	12
						39	WAWEL	11.03.1998	10	29	10
						40	WIRTUALNA	07.05.2015	10	9	10

Source: own calculations.

Table 3
The length of the three moving averages that maximize the transaction system in the case of companies included in the sWIG80 index

Number	Company	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3	Number	Company	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3
1	ABC DATA	17.06.2010	25	15	12	41	MCI	01.02.2001	7	16	5
2	ABPL	21.09.2006	3	4	3	42	MEDI-CALALG	09.11.2011	20	30	30
3	ACAUTOGAZ	11.08.2011	10	5	3	43	MENNICA	02.04.1998	3	4	4
4	AGORA	20.04.1999	3	5	3	44	MIRBUD	29.12.2008	3	4	3
5	AILLERON	12.10.2011	6	5	4	45	MLPGROUP	28.10.2013	6	5	3
6	ALCHEMIA	19.05.1998	4	12	25	46	MONNARI	20.12.2006	29	26	4
7	ALTUS TFI	20.08.2014	3	4	3	47	NETIA	15.06.2000	3	15	3
8	ALUMETAL	17.07.2014	5	6	4	48	NEUCA	30.09.2004	4	3	27
9	AMBRA	22.06.2005	20	14	9	49	NEWAG	05.12.2013	5	12	5
10	APATOR	24.04.1997	28	30	12	50	OAT	19.04.2018	4	5	4
11	ARCTIC	23.10.2009	29	32	28	51	OPONELOPL	12.09.2007	9	17	4
12	ASBIS	30.10.2007	6	3	3	52	OVOSTAR	29.06.2011	8	9	8
13	ASSECOBS	19.11.2007	7	9	9	53	PBKM	29.04.2016	23	20	10
14	ASSECOSEE	28.10.2009	18	29	21	54	PCCROKITA	25.06.2014	3	5	3
15	ASTARTA	17.08.2006	3	5	3	55	PCM	16.04.2014	4	6	3
16	ATAL	23.07.2015	30	28	23	56	PEKABEX	08.07.2015	4	3	3
17	ATMGRUPA	19.01.2004	4	5	3	57	PEP	13.05.2005	7	11	7
18	AUTO-PARTNER	06.06.2016	22	15	5	58	PGSSOFT	29.10.2008	18	7	18
19	BAHOLDING	19.06.2008	7	26	24	59	PHN	13.02.2013	9	27	8
20	BIOTON	16.03.2005	18	29	15	60	POLICE	14.07.2005	7	27	6
21	BOS	03.02.1997	14	6	4	61	POLNORD	18.12.1998	25	30	10
22	BSCDRUK	04.01.2011	4	9	3	62	QUERCUS	11.09.2008	27	28	3
23	CLNPHARMA	01.12.2016	7	5	7	63	RAFAKO	07.03.1994	6	28	28
24	COMP	14.01.2005	6	8	3	64	RAINBOW	09.10.2007	4	7	4
25	CORMAY	20.08.2008	10	5	3	65	SELVITA	14.07.2011	11	5	3
26	DEBICA	21.11.1994	5	12	28	66	SERINUS	25.05.2010	21	29	10
27	DOMDEV	24.10.2006	6	33	3	67	SKARBIEC	18.11.2014	3	25	8
28	ECHO	05.03.1996	3	27	3	68	SNIEZKA	31.12.2003	27	23	18
29	EKOEXPORT	16.07.2009	7	5	18	69	STALEXPORT	26.10.1994	5	8	3
30	ELBUDOWA	09.02.1996	5	23	3	70	TIM	16.02.1998	3	7	3
31	ELEMENTAL	12.07.2012	21	20	5	71	TORPOL	05.09.2014	3	10	9

Table 3, cont'd

Number	Company	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3	Number	Company	Date of the first listing on the WSE	Length of the moving average N_1	Length of the moving average N_2	Length of the moving average N_3
32	ENTER	18.01.2016	6	3	3	72	TOYA	12.08.2011	5	20	3
33	FERRO	14.04.2010	5	19	9	73	TSGAMES	11.05.2018	4	5	4
34	IDEABANK	29.04.2015	4	4	3	74	VIGOSYS	24.11.2014	10	3	3
35	IMCOMPANY	05.05.2011	6	14	3	75	VISTULA	30.09.1993	8	11	7
36	IMPEXMATAL	24.06.1997	3	5	3	76	VIVID	11.06.2012	7	6	7
37	KOGENERACJA	26.05.2000	3	6	3	77	VOXEL	11.10.2011	21	4	18
38	KREZUS	12.06.1997	5	9	3	78	WIELTON	28.11.2007	3	17	5
39	LENTEX	08.05.1997	4	6	3	79	XTB	17.05.2016	17	19	7

Source: own calculations.