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RELIABLE SIGNALS BASED ON FISHER TRANSFORM FOR ALGORITHMIC TRADING

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Trading and investment on financial markets are common activities today. A very high number of investors, companies, public or private funds are buying and selling every day with a single purpose: the profit. The common questions for any market participant are: when to buy, when to sell and when is better to stay away from the market risk. In order to answer all these questions, many trading strategies are used to establish the best moments to entry or to exit the trades. Due to the large price volatility, a significant part of the trades is set up automatically today by computers using algorithmic trading procedures. For this particular field, special aspects must be met in order to automate the trading process. This paper presents one of these mathematical models used in automated trading systems, a method based on the Fisher transform. A general form of this method will be presented, the functional parameters and the way to optimize them in order to reduce the risk. It will be also suggested a method to build reliable trading signals with the Fisher function in order to be automated. Three different trading signal types will be explained together with the significance of the functional parameters in the price field. A code sample will be included in this paper to prove the simplicity of this method. Real results obtained with the Fisher trading signals will be also presented, compared and analyzed in order to show how this method can be implemented in algorithmic trading.

Keywords: **Financial markets, Fisher transform, Algorithmic trading,**
High frequency trading, Automated trading systems

JEL Classification: **M15, O16, G23, M21**

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1. Introduction

To be involved in the financial market is on trend today. Millions of private traders or investors are buying and selling every day different kind of equities, stocks, indices, commodities or currencies. The reason is only one: the profit, as difference between the buy and the sell price. Each participant tries to buy cheap and to sell more expensive after a time period. The idea is simple but many times the market price is turning against the trade. A common scenario is after a period when the price increased and a buy trade is set up, the price starts to decrease continuously. Sometimes the opening price cannot be retrieved and the trade turns into a loss. These cases can be avoided or managed using a good trading strategy.

The main questions of each trader or investor participating in the financial markets are: when to buy, when to sell and when it would be better not to trade. The perfect trading strategy does not exist. To answer the common questions regarding the trading decisions, many trading strategies were developed. As a result of the widespread development of the electronic trading, under the conditions of the high price volatility on the financial markets today, an important part of the trades is set up automatically.

“In electronic financial markets, algorithmic trading refers to the use of computer programs to automate one or more stages of the trading process” (Nuti, Mirghaemi, Treleaven & Yingsaeree, 2011, p.22). Algorithmic trading seems to be the future of this field, as long as “large general financial volatility may increase uncertainty about the economic environment, with long-lasting effects as investors demand a higher risk” (Funke & Goldstein, 1996, p.215). Today the trading decisions are built almost instantly by computers using algorithmic procedures. This paper will present one of these computational models.

The method presented is based on fisher transform applied to the time price series. A first version of this method was presented by Ehlers (2002). The methodology to apply Fisher transform in algorithmic trading is a subject less developed in the literature. A generalized form of the Fisher transform for algorithmic trading will be presented in this paper together with the parameters that can be optimized in order to reduce the risk. It will be presented a practical method to use the Fisher function in order to generate automated trading signals for financial markets. To answer the questions regarding the buy and sell moments, and to build a possibility to automate these decisions, a practical method to compute trading signals based on the Fisher function will be included in this article. Three different trading signal types will be explained together with the significance of their functional parameters. A code sample for the Fisher indicator will be inserted in this paper in order to show the simplicity of this method. To prove the method, some real trading results obtained with the Fisher trading signals will be presented, compared and analyzed in order to qualify the method.

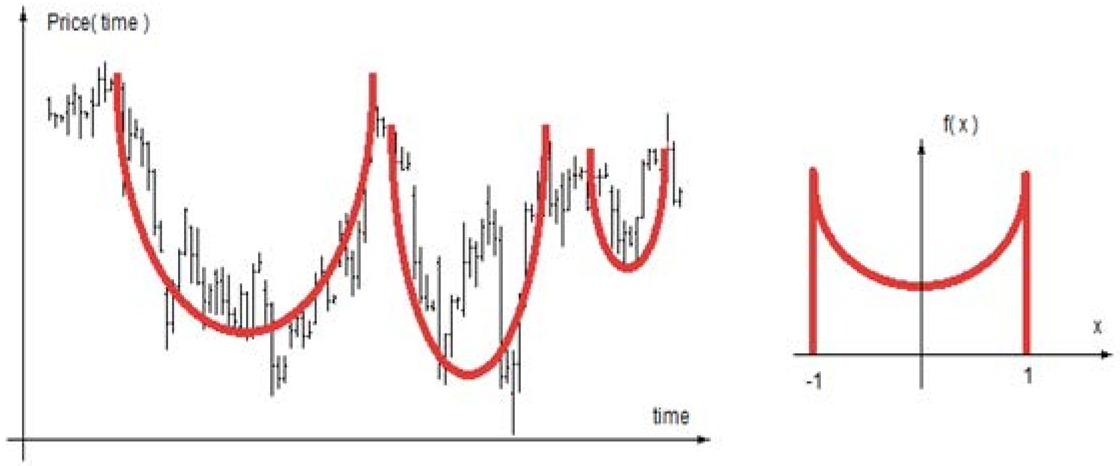

Figure 1: Similarity between the time price evolution and the square wave probability function.

In any financial market, due to the economic news releases and as result of the changes in time of the investors' risk appetite, the price makes local maximum and minimum points on a time interval. Based on this conjecture the price evolution between two maximum points can be considered similar with the so called wire distribution, the square wave probability function which registers maximum values at the ends of the interval and makes a minimum point on the middle. Building a mathematical transformation of the price function to a particular known function limited into [-1; 1] interval, can give us the possibility to predict the maximum and the minimum points of the price just analyzing the transformation function. This idea is usually applied in engineering but, as we will see the method gives us very good results for the financial markets. Finding the minimum point of the transformation function will indicate when the price series will turn in order to increase again to the new values of the next maximum local price. This will give us a method in order to build a trading signal to automate the decision about when to buy and when to sell depending on the values and due to the variation of the Fisher function.

2. Fisher Function

The method suggested is based on the assumption that the price makes local maximum points time to time. Between two maximum points a local minimum price always exists. Usually this is a common behavior of the price in financial markets even the number of the time intervals between two maximum points varies. Starting from this idea we will use a transformation function between the price function and a known function that will describe the square wave probability function presented in Figure 1. This transformation is just a similarity between the two, when the price reaches a maximum value the price transformed function makes a maximum. When the price reaches a minimum value, the model function will have a minimum point. The model function is known and described by the conditions imposed for its first derivate, as we will see below.

There are several functions used in practice to make this price transformation. The common parts of all these functions is that they are described on [-1; 1] interval and they have the same behavior of the first derivate: a root of the first derivate in the middle of the interval (corresponding with the minimum price value), high values of the first derivate on the ends of that interval (corresponding with the maximum points of the price at the end of the time interval considered), negative first derivate on [-1; 0] (as price descending from the local maximum point to the minimum) and positive first derivate on [0; 1] interval (as the price increases again after the minimum local point to the next maximum local point). In this paper we aim to present the usage of the Fisher transform function in order to describe the first derivate of the price transformation. The Fisher function is:

$$f'(x) = \frac{1}{2}\ln\left(\frac{1+x}{1-x}\right) \tag{1}$$

where ln is the natural logarithm.

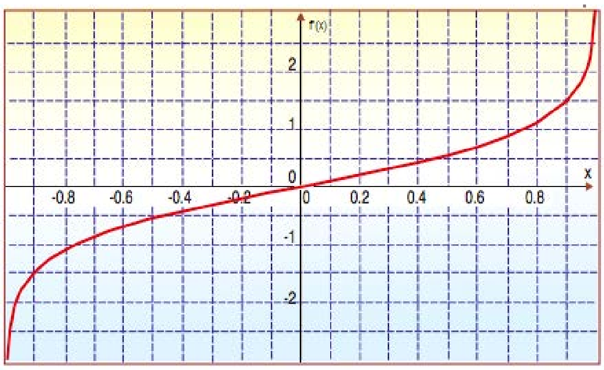

Figure. 2. Fisher transform function

2.1. Fisher transformation

As can be seen in figure 2, the Fisher function respect all conditions imposed for the first derivate of the wire function assimilated with the price behavior on a time interval. The derivate has a root in that interval and it takes negative and respectively positive values before and after the root. The variable x is defined in the [-1; 1] interval. The price function defined on the time interval is transformed into a function into a new space defined in the interval [-1; 1]. The transformation conditions are defined using only the first derivate of the transform function. Working only with the first derivate, the analytical form of the transformation function is not important because the model will continue to use only the first derivate of that function. To find the function anyone can integrate the formula (1).

“Based on the assumption that the price cycle will continue into the future” (Ehlers, 2002, p. 40), analyzing the Fisher function will determine when a local minimum point was passed in order to predict the next ascending period of the price values to the next local maximum value. This will be assimilated with a buy trading signal. When the first derivate of the transformation function will pass through zero, the minimum point for the price is nearby. We use the “nearby” term because the price in financial market is not a continuous function. The price is given as a discontinued value in time. The values in a time interval can be defined as a global polynomial interpolation function. To simplify the model, the price function can be assimilated with a Spline function (Berbente, Mitran & Zancu, 1997, p. 9), as a straight line between two consecutive time points.

Having the transform function defined by the formula (1) we can make a real time analysis if we link the price values with the x value of that function. Because the x is defined on [-1; 1] interval we have to reduce the price interval. For than we will consider formula (2). For a time series where the price value for the (i) interval is noted with (p_i), we can consider the transformation:

$$p_i \to \frac{p_i - p_{\min}}{p_{\max} - p_{\min}} \tag{2}$$

In the formula (2), the terms ($p_{\min}$) and ($p_{\max}$) are the minimal and respectively the maximal values of the price in the considered time interval. Due to the fact that the price in financial markets historical data is given by a particular data structure which define High, Low, Open and Close values on each time unit, the price Fisher Indicator will use an average price value for each time unit given by:

$$\bar{p}_i = \frac{High_i + Low_i}{2} \tag{3}$$

and the general form of the price transformation for a time price series is given by the formula:

$$p_i \to \alpha\left(\frac{\bar{p}_i - p_{\min}}{p_{\max} - p_{\min}} - \beta\right) + \delta \cdot \bar{p}_{i-1} \tag{4}$$

where α, β and δ are optimization coefficients in order to improve the method. Ehlers (2004) propose the coefficients: α=0.66, β=0.5 and δ=0.67. We found that optimization of these parameters can gives different optimal values for each financial market, for a specified number of time units (n). These parameters are very important to be optimized depending on the market and on the timeframe used for model application, especially when it is about the Fisher trading signals included in the third chapter of this paper.

The optimization method for the functional parameters of the Fisher transform is to consider different values for each parameter and to compute the trading results for a longer period of time, based on the historical price series. For each set of functional parameters the gradient of the Fisher transform function will be different and as consequence the trading results will be different because of some delays of the trading signals.

2.2. Fisher indicator

The Fisher transform of the price for Frankfurt Stock Exchange Deutsche Aktienindex DAX30 (Börse, 2018) for a 65 days interval is presented in figure 3. The current Fisher transform values for the current interval are represented together with the values for the last time interval, in order to reveal more accurate the turning points of the Fisher transform function. As can be seen in figure 3, when the Fisher function turns, the price follows the same direction even sometimes there is a small delay between the two functions. This is the behavior assured by the formula (4) transformation. The Pearson's correlation indicator between the price evolution and the Fisher transform function, calculated for a period of ten years, with a time interval variable between 20 and 100 time units, for DAX30 index, with different timeframes, has values between the minimum 0.62315 and the maximum 0.99983. The correlation indicator was calculated considering the price transformation presented, with variation of 1 value for the ascending price intervals and 0 values for descending price intervals. The values obtained indicate a very good and positive correlation between the increasing or decreasing of the price and the evolution of the fisher function. The high values of the correlation indicator makes this method reliable, fact confirmed by the results presented later.

Analyzing the Fisher indicator, a good prediction can be made at least in order to decide the direction of the price for the next period. It is assumed that the method presented here does not intend to predict the price value for the next time interval. The method intends to establish when the price passed the minimum point and is ready to entry in the next increasing period. The method presented here can gives us an indication for entry and exit signals based only on the Fisher values not on the price values. As can be seen in Figure 3, after the Fisher function passed through zero value, the price starts to increase to a local maximum point. This can be assimilated with a prediction in order to establish the direction of the price not the next value of the price. When the price slows down from the ascending movements, we can see the Fisher indicator turning into a descending interval. A complete trading signal can be built between B and C points in Figure 3, at B a buy signal can be generated by the Fisher function and at C point an exit trade signal can be delivered by the same transform function. As can be seen, the decisions in this model are based only on the transform function not on price values. In the next chapter we will see how automated trading signals can be built in order to trade the Fisher function. Some real trading results will be presented in chapter 4.

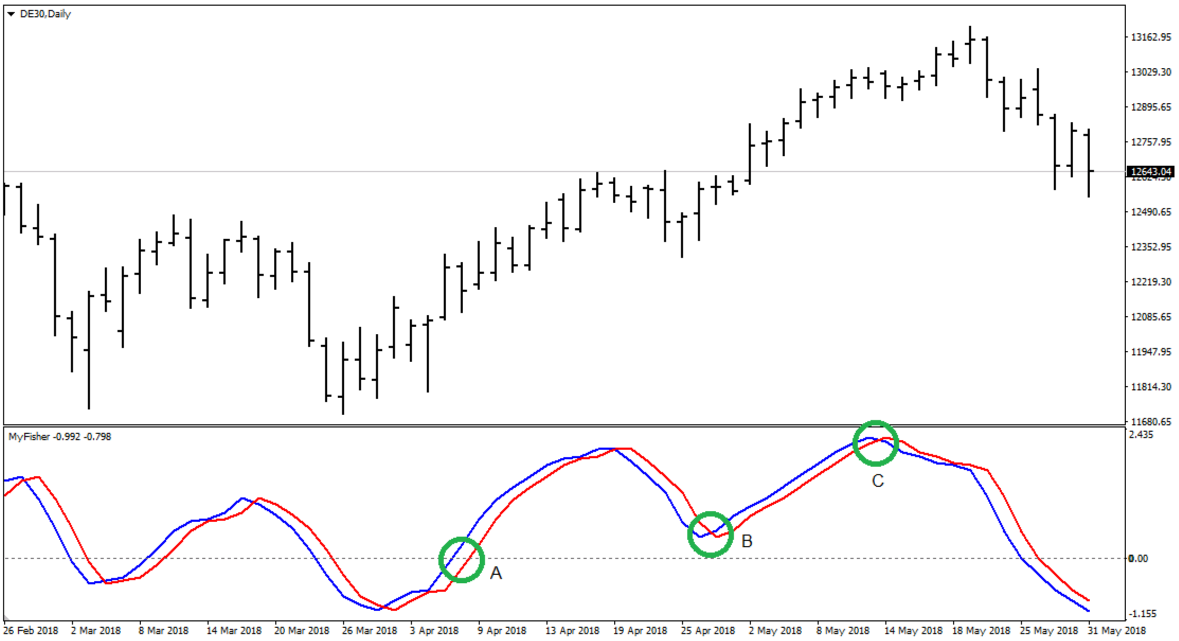

Figure 3. Price Fisher transform indicator for daily price of DAX30.

```
#property indicator_separate_window
#property indicator_buffers 2
#property indicator_level1 0
int MyPeriod=10; double Fisher[], History[];
int init(){SetIndexStyle(0,DRAW_LINE,1,2,Blue);
           SetIndexStyle(1,DRAW_LINE,1,2,Red);
           IndicatorDigits(Digits+1);
           SetIndexBuffer(0,Fisher);
           SetIndexBuffer(1,History);
           IndicatorShortName("MyFisher");
           return(0);}
int start(){double Average, MinL, MaxH, Value, LastValue, LastFisher;
            for(int i=Bars-2-MyPeriod;i>=0;i--)
               {MaxH=High[Highest(NULL,0,MODE_HIGH,MyPeriod,i)];
                MinL=Low[Lowest(NULL,0,MODE_LOW,MyPeriod,i)];
                Average=(High[i]+Low[i])/2;
                Value=0.33*2*((Average-MinL)/(MaxH-MinL)-0.5)+0.67*LastValue;
                Value=MathMin(MathMax(Value,-0.99999),0.99999); LastValue=Value;
                Fisher[i]=0.5*MathLog((1+Value)/(1-Value))+0.5*LastFisher;
                LastFisher=Fisher[i]; History[i]=Fisher[i+1];}
            return(0);}
```

Figure 4. **Price Fisher transform indicator code in Multi Query Language**

A sample code for the price Fisher transform indicator in multi query language (MQL) is presented in figure 4. As can be seen, the implementation in algorithmic trading of this method is a simple one. This is the most important advantage of this method. The good results obtained and the simplicity of the method make this model to be a very attractive one.

3. Trading signals

The intended purpose of the method presented is to automate the trade. To include the Fisher function in an algorithmic trading program means to build some logical trading conditions. We will call these conditions as trading signals. These will be Boolean variable with an explicit meaning: when a buy signal is “true”, the software will send an automated buy order; when a sell signal is “true”, the program will send a sell order. It is assumed that if in a moment of time a buy signal is “true”, the model must assure that the sell signal is set as “false”. While the trading signals are depending on the monotony of the Fisher function, this last assumption is by default respected as we will see.

To build trading signals using the Fisher transform of the price means to analyze the turning points of the Fisher function. Based on the hypothesis that the price evolution is similar with the wire distribution function (Figure 1), near a minimum point of the Fisher function the price reaches also a minimum point and the future values of the price will increase in order to register a new maximum point. This can be a buy signal.

After the maximum point of the Fisher function, when the Fisher values starts to decrease, based on the same assumption, the price will turn down to decreasing values. This means the buy signal is no longer available; a sell decision must be in place. Usual the buy decision is not taken immediately after the turning point; another one or two time units are expected to generate a good signal confirmation. The buy signal can be built as:

$$BuySignal_i = (F_i > F_{i-1} + \xi) \wedge (F_{i-1} > F_{i-2} + \xi) \tag{5}$$

where (F_i) is the time value of the Fisher function, (∧) is the logical and operator and ξ is the minimal gradient parameter in order to filter the trades. When the distance between (F_i) and (F_{i-1}) is very small, the price movement is not yet a significant one and the trade can fail. For this reason, using a higher ξ value will generate better trades. This functional parameter is a subject of the optimization process for each market. Analyzing the Fisher graph we can see that the condition (5) is also available in some points nearby the local maximum values of the Fisher function. This means some buy trades accomplished with (5) can be opened near the turning points of the price, which definitely is not a good idea. In order to avoid this, the buy signal is changed with two additional conditions as:

$$BuySignal_i = (F_i > F_{i-1} + \xi) \wedge (F_{i-1} > F_{i-2} + \xi) \wedge (F_i > -\rho) \wedge (F_i < \rho) \tag{6}$$

where ρ is a distance from the 0 value of the Fisher function where the buy signal is not any more considered. In practice also too early signals do not give very good results and to avoid these cases the signal is not considered when the (F_i) value is outside the interval [-ρ; ρ]. The ρ parameter is also an optimization process and it is established statistically by repetitive optimizations using a large interval of the price series. As we can see, the buy signal defined by (6) uses only the price Fisher transform function values. The price values are not there and the model do not try to predict the price values. We will call this signal the Fisher signal. In the same manner the sell signal can be built for markets where short positions can be considered with the formula:

$$SellSignal_i = (F_i < F_{i-1} - \xi) \wedge (F_{i-1} < F_{i-2} - \xi) \wedge (F_i > -\rho) \wedge (F_i < \rho) \tag{7}$$

A particular point of the Fisher function is the zero point (A point in Figure 3.). This is the point where the minimal value of the price is present. After this point the price values start to increase. For very volatile markets where the price does not have large increase periods or to trade with shorter timeframe, as all cases in high frequency trading, the point A is considered the only one available Fisher signal using the relations

$$\begin{cases} BuySignal_i = (F_i > 0) \wedge (F_{i-1} < 0) \wedge (F_i > -\rho) \wedge (F_i < \rho) \\ SellSignal_i = (F_i < 0) \wedge (F_{i-1} > 0) \wedge (F_i > -\rho) \wedge (F_i < \rho) \end{cases} \tag{8}$$

Once the Fisher function has gone through zero ascending, a buy signal is considered. When the Fisher function has gone through zero descending, a sell signal is considered. We have to mention that the Fisher trading signals are only entry points in the market. The exit points are treated separately and they are not the subject of this paper. The trading signals given by (6) and (7) are usually very accurate for higher values of ξ. When the gradient of the Fisher function has small values, meaning the ξ parameter is smaller, a lot of trades can be generated by the Fisher signal but some of them are false signals because the changes of the price are not important ones. For these cases additional conditions can be applied in order to build reliable trading signals. A good filter for the Fisher transform function is the price cyclicality function (Păuna & Lungu, 2018). Noted with (PCY_i), the price cyclicality function will complete the Fisher trading signals:

$$\begin{aligned} BuySignal_i = {} & (F_i > F_{i-1} + \xi) \wedge (F_{i-1} > F_{i-2} + \xi) \wedge (F_i > -\rho) \wedge (F_i < \rho) \wedge \\ & (PCY_i > PCY_{i-1}) \wedge (PCY_{i-1} > PCY_{i-2}) \wedge (PCY_i > -\varphi) \wedge (PCY_i > \varphi) \end{aligned} \tag{9}$$

where φ define the trust interval for the PCY function. The usage of (PCY_i) in relation (9) makes a significant filtration for the Fisher signals in order to consider only that trades with an ascending cyclicality function and exclude all the cases when the price is oversold or overbought by limiting the values of the PCY in the [-φ; φ] interval. We will call this signal the Fisher cyclicality trading signal. As will be seen in the next chapter, the signals given by (9) formula will generate a higher number of trades than the simple Fisher signal accomplished with (6).

A good particularity of the Fisher transform function is that the methodology can be applied not only to the price values. A particular indicator can be obtained applying the Fisher transform to the moving average of the price. Starting from the same assumption that the moving average will take a minimal local value between two maximal local values, applying the Fisher transform to the moving average of the price will give us the possibility to predict higher values of the moving average after a minimum point of the Fisher function.

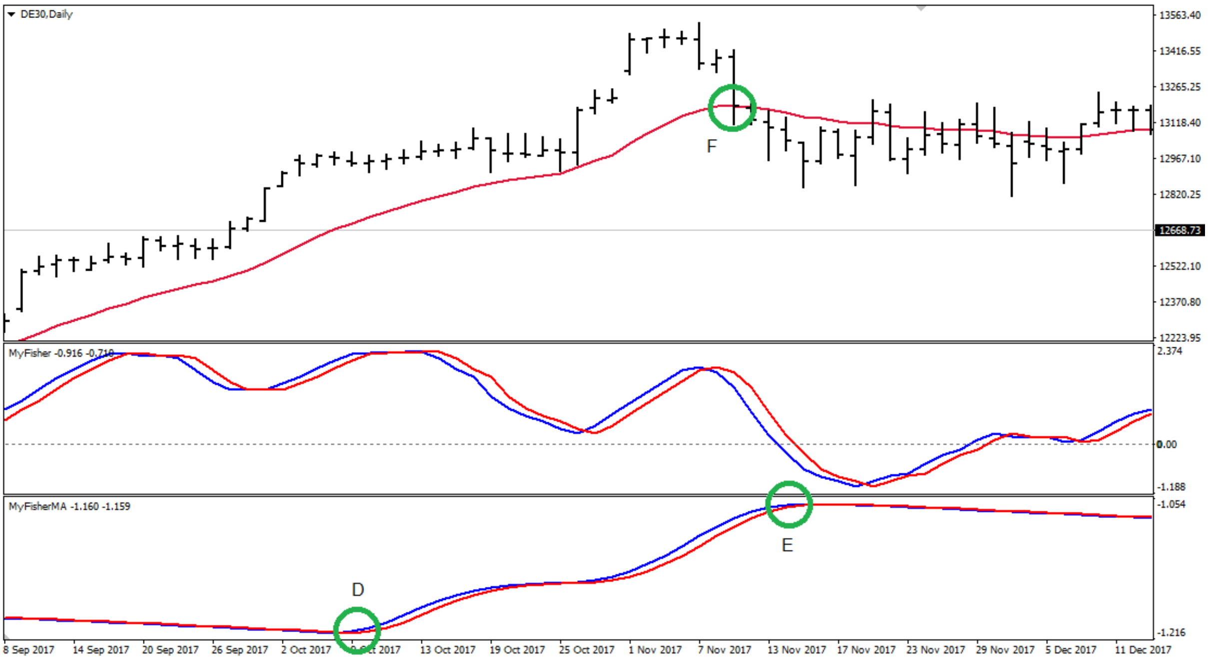

***Figure 5.* Fisher transform of the moving average of the price**

The Fisher transform applied to the 10 period exponential moving averages for a daily price time series of DAX30 Index is presented in figure 5. As we can see, after the D point a significant increase in values of the moving average occurs, meaning that a significant upward movement of the price can be expected until the E. Trading signals with the Fisher transform of moving average of the price can be built similarly with (6), (7), (8) and (9) formulas.

4. Trading results

It this chapter we present the trading results obtained with the Fisher trading signals indicated above. The results were obtained using TheDaxTrader (Păuna, 2010), an automated trading system that uses Fisher signals in order to generate buy trades for DAX30 index. The results presented in table 1. were obtained in the period 01.06.2015 – 31.05.2018 using a fixed target of 10 points for each trade. This consideration takes place instead of an additional exit signal conditions that are not subject for this paper.

The DAX30 index was traded as contract for differences (CFD) with a spread of 1 point. The exposed capital involved and the risk management were accomplished using the "Global Stop Loss Method" (Păuna 2018). The price Fisher transform and the cyclicality function were computed for H4 timeframe interval. An additional condition was imposed regarding the hourly intervals of the executed trades between 8:00 and 16:00 coordinated universal time (UTC). In table 1. are presented the trading results for:

- Fisher trading signals given by (6) with ξ=0.45 and ρ=0.50;
- Fisher trading signals given by (8) with ρ=0.50;
- Fisher cyclicality trading signals given by (9) with ξ=0.10, ρ=0.50 and φ=5 and
- all the above signals assembled together. The capital evolution for these last results is presented in Figure 6.

Table 1. **Trading results obtained with the long Fisher signals**

	Total trades	Losing trades	Profit	Drawdown	RRR	Absolute drawdown	Absolute RRR
(6) **ξ=0.45 ρ=0.50**	10	0	2578	3744	1:0.69	2729	1:0.94
(8) **ρ=0.50**	138	0	36802	7690	1:4.79	6320	1:5.82
(9) **ξ=0.10 ρ=0.50 φ=5**	40	0	10323	8896	1:1.16	6323	1:1.63
(6), (8) and (9) **assembled together**	159	0	42370	9079	1:4.67	6321	1:6.70

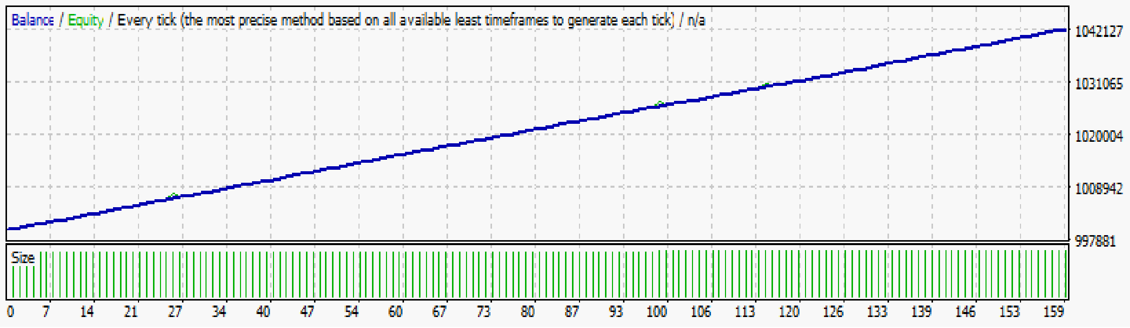

Figure 6. **Capital evolution as a result of all Fisher trading signal types assembled together**

As we can see, the number of trades made by the signal with (6) formula for a high value of ξ is reduced. A significant number of trades can be generated for lower values of the ξ parameter but the drawdown of the results is higher, a part of these involving a higher risk. For the trading results presented, all functional parameters were optimized in order to obtain no losing trade and to reduce the risk involved.

As we can see in the figure 6, the presented trading model permits this objective to be realized. No losing trade was registered in a 35-month interval. This fact allows us to say that the trading signals obtained with Fisher method are reliable trading signals.

A significant large number of trades were made by the trading signal (8). A very good risk to reward ratio (RRR) was obtained for this type of signal. As we can see in the table 1, for each 1 dollar risked the 4.79 dollars were obtained as profit. The drawdown reflects the exposure capital; it is the risk recorded during the trades. The absolute drawdown represents the drawdown from the initial capital. As we can see both values are in the normal interval, much lower valued than the profit obtained.

The signals made by (9) are also significant when it is about the number of trade executed and the profit level obtained. All three signal types assembled together gives us a very good return. With only 159 trades during a period of 35 months, the Fisher trading signals produced 42,370 dollars profit with a maximum risk of 9,079 and an absolute drawdown 1:6.70 trading DAX30 Frankfurt Stock Exchange Index.

Based on the fact that the trading methodology presented in this paper makes a significant number of profitable trades with a very low number of losing trades (even with no losing trades for the proper optimization parameters set as it was seen above), the Fisher trading methodology deserve a special attention. In addition, the simplicity of this model makes it attractive for algorithmic trading.

In order to reveal the advantages of the fisher methodology we have made a comparison with other known trading methods. The results presented in Table 2. were obtained using algorithmic trading in the same period of time (01.06.2015 – 31.05.2018), on the same financial market (DAX30) with the same ten points target.

The known trading methods used were the “Moving averages perfect order methodology” (Lien, 2009), “Parabolic stop and reverse methodology” (Wilder, 1978) and “Relative strength index methodology” (Connors & Alvarez, 2009). Each method was optimized to obtain the best efficiency for the traded financial markets. In Table 2 it can be seen that Fisher methodology makes a significant larger number of trades with the higher risk and reward ratio

(RRR). These results are an additional confirmation that Fisher transform gives us a reliable trading methodology for algorithmic trading.

Table 2. **Comparison between Fisher trading signals and other known trading methodologies**

	Total trades	Losing trades	Profit	Drawdown	RRR	Absolute drawdown	Absolute RRR
Fisher signals (6), (8) and (9)	159	0	42370	9079	1:4.67	6321	1:6.70
Moving averages perfect order signals	96	28	18045	8712	1:2.07	5871	1:3.07
Parabolic stop and reverse signals	102	31	18816	6011	1:3.13	5418	1:3.47
Relative Strength Index signals	68	6	16372	5901	1:2.77	5272	1:3.10

The author uses the Fisher trading signals presented in this paper since 2010 year. This methodology was included in TheDaxTrader automated software from the beginning. The results obtained with this methodology were always the same. With a proper optimization parameters set, the Fisher signals generate only profitable trades in the stock markets. This methodology was tested, implemented and used with the same good results for a representative number of financial markets: Deutscher Aktienindex (DAX30), Dow Jones Industrial Average (DJIA30), Financial Times London Stock Exchange (FTSE100), Cotation Assistée en Continue Paris (CAC40), Swiss Stock Exchange Market Index (SMI20), Australian Securities Exchange Sydney Index (ASX200), Tokyo stock Exchange Nikkei Index (Nikkei225), NASDAQ100 Index, Standard & Poor’s Index (S&P500) and Small Capitalization US Index (Russell2000). Also with good and stable results the Fischer methodology presented in this paper were applied for Gold and Bent Crude Oil financial markets starting with 2012 year.

5. Conclusions

Fisher price transformation can predict the turning points of the price. Buy and sell trading signals can be built based on the Fisher function’s values. The prediction for a future price value is not an objective of this method. The only one minimal point of the Fisher function on the considered interval permits to determine when the price start to increase to a new local maximum value. This point is the base for a buy signal. The sell signals are met in the same way working with the descending intervals of the Fisher function.

Being exclusively a mathematical model, the Fisher signals can be automated for algorithmic trading. The functional parameters of the Fisher methodology presented must be optimized for each traded market. There is no general parameter set. Each market has its own behavior; the optimal trading results are met when the functional parameters of the Fisher method are optimized especially for that market.

Good trading results are obtained combining the Fisher trading signals with other indicators, especially to avoid the cases when the price is overbought or oversold. These two concepts are not included in the Fisher model; additional functions can be added in order to filter the extreme price intervals. The Fisher method can be also applied to predict the evolution of any other indicator such as moving average. In this way a considerable number of combined trading signals can be built.

With the right parameters set, the Fisher trading signals can generate trading results with a good risk to reward ratio. Even "loses are a part of trading" (Ward, 2010, p.137) and must to be accepted from time to time, the right parameters set can gives us a long line of winning trades with no losing trade as we saw. With these results it can be said that Fisher signals are reliable trading signals for financial markets and a very good solution for algorithmic trading.

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