VOLUME CYCLICALITY. RELIABLE CAPITAL INVESTMENT SIGNALS BASED ON TRADING VOLUME INFORMATION

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VOLUME CYCLICALITY. RELIABLE CAPITAL INVESTMENT SIGNALS BASED ON TRADING VOLUME INFORMATION

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Capital investment is a sustained activity nowadays. The buy and sell decisions are usually made in technical analysis using the price quote evolution in time. Another useful information provided by any stock exchange is the trading volume for each time interval. The volume information is usually hard to be included in a trading or investment strategy, having an unstable and discontinued evolution in time. Some obsolete ideas indicate a favorable entry period after a maximal traded volume value interval, but today, on the high price volatility markets, when a maximal value is detected, usually is too late for a convenient price entry on that market. This paper presents a mathematical model specially designed for fast and instant market entry decisions based only on the traded volume information. It was found that even the traded volume variation in time is discontinued, a cyclical phenomenon is present in all markets. With the proper mathematical method, the Volume Cyclicality function can be computed in real-time in order to build reliable capital investment signals. The model presented in this paper fills an essential gap in the literature, and it was tested for more than ten years on the most important stock exchanges in the world. Investment results are also included in this paper to prove the efficiency and utility of the presented method. The Volume Cyclicality function is an exclusively mathematical model, and it can be applied in any automated investment software system to improve capital efficiency.

Keywords: **Capital investment, Technical analysis, Trading volume, Volume cyclicality, Trading strategy, Algorithmic trading**

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

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1. Introduction

Financial trading and capital investment are everyday activities nowadays. With the single purpose of making a profit, millions of individuals or companies are participating every day in the free markets. The buy and sell decisions are usually founded on the technical analysis of the time price evolution. A considerable number of strategies to analyze the price action are published in the specialized literature. This paper will treat a less discussed and developed subject, and this is about how to build a reliable investment decision based on the trading volume information.

Any stock exchange is providing today the real-time price quotes, and the trading volume on a specific time interval. Both are valuable pieces of information that can be used to build a buy or sell decision. The trading volume is "the number of shares exchanged between buyers and sellers during a given period of time, typically a day." (Dormeier, 2011) The trading volume information is less used in common algorithmic trading strategies. The main reason is that the variation of the traded volume in time is a discontinued and unstable function. This fact can be easily seen in figure 1. Under the price graph of the DAX30 Frankfurt Stock Exchange Deutscher Aktienindex daily price evolution, the trading volume for each day is plotted. As can be seen, there are days with a higher traded volume and days when the investment appetite decreases, without any rule or significant trend.

The question this paper will answer to is how to use the traded volume information to build reliable investment decisions and how to combine trading volume with price evolution to increase investment capital efficiency. A new function will be introduced: Volume Cyclicality function (VOC), which is computed using only the traded volume information, without any dependence with the price quotes. The general study of the cyclic behavior of any time-evolving phenomena is essential, giving us the possibility to find the minimal and maximal points in real-time and clearly define the ascending and descending periods. In this way, important decisions can be made based on cyclical behavior over time. This research has found that the Volume Cyclicality function has a significant correlation with the price evolution, and it can be used with outstanding results to include the volume information in trading and investment decision strategies and to build buying and selling signals depending on the trading volume information. The importance of the Volume Cyclicality function analysis is highlighted by the results obtained in a joint study with the Price cyclicality function. These two functions can significantly improve the performance of any trading or investment strategy to increase capital efficiency.

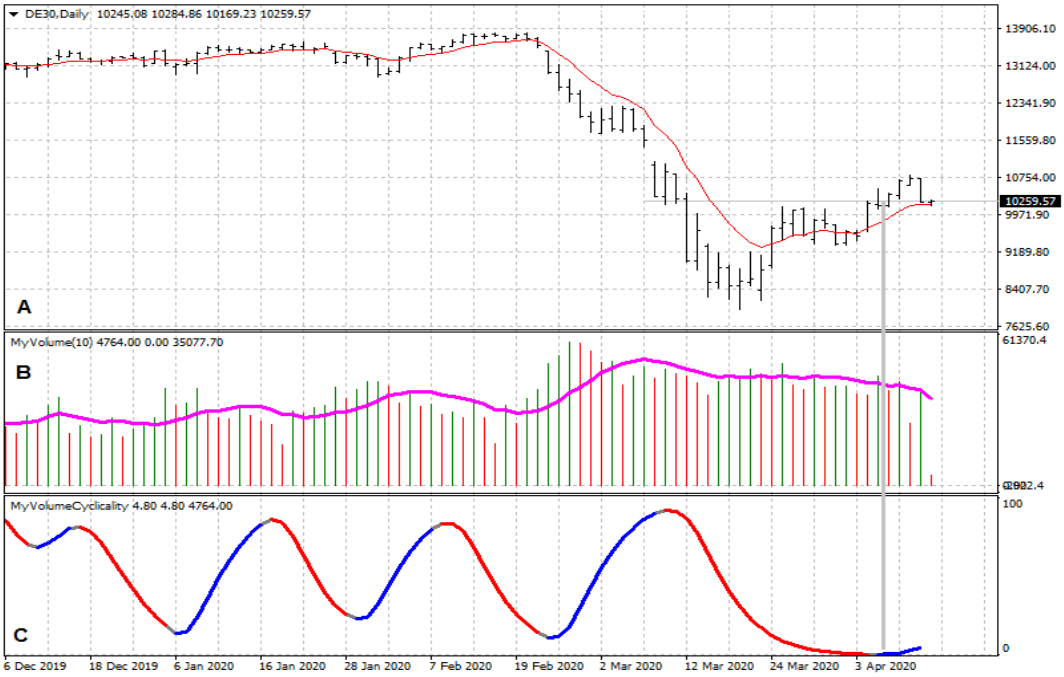

Figure 1. Volume, average volume, and Volume Cyclicality function for DAX30 Index.

2. Literature review

In 3087 trading books and 2811 published articles about technical analysis, strategies, and algorithmic trading studied to write a literature review, no paper is presenting a mathematical model to study the cyclic behavior of the trading volume. The present paper fills this important gap.

In the literature, many investments or trading strategies "involve investigating patterns based on historical trading data (past price data and trading volume) to forecast the future movement of individual stocks or the market as a whole." (Focardi & Fabozzi, 2004) However, many found strategies do not include the trading volume information accurately. Usually, the volume is linked with a price evolution pattern that conducts an entry decision if the traded volume is growing up, thinking that many other investors are making the same decision in that interval. "A huge pickup in volume can propel the stock into its next trading range." (Shkolnik, 2003) On a price market bottom interval, "a high-volume spike often occurs." (Appel, 2005) "Volume confirms the trend." (Monte & Swope, 2008)

Some authors link a decreased trading volume to an up-pricing movement by a bear long time trend, once the investors seeing the weakness "will not be participating in the current up-move." (Williams, 2005). Some strategies are using a moving average of the trading volume, transforming in this way the discontinued volume function into a more convenient evolution. No author can identify the idea of using volume averages instead of the nominal value of the traded volume. Some authors recommend empirical relations between volume, price, and trading decisions, as can be found in (Chordia, Roll & Subrahmanyam, 1998).

Other authors indicate a proper market entry when "the volume trend diminishes over time until the breakout." (Bulkowski, 2005) A receding trading volume trend can signify that the majority of investors have already entered that market, and a significant movement is likely to come. A different approach is presented in (Barclay & Hendershott, 2003) analyzing the low trading volume after hours, and considering as a significant signal the measure of the traded volume of US stocks listed on foreign exchanges outside the US, stocks that are traded outside the regular trading hours of the major US stock exchanges. An intraday analysis of the intraday trading volume is also made (Chan, Chockalingam & Lai, 2000). Other authors are studying the idea to link the trading volume of specific time intervals, a particular day of the week, or weekend as in (Brooks, 1997). Other authors link the trading volume patterns with specific hour intervals to fundament a trading decision (Foster & Viswanathan, 1993).

Analyzing the trading volume information is a sustained criterion for an investment portfolio selection. In the stock market, the high volume criteria are well considered by the professionals. "Where there is volume, there will be trends." (Pruitt & Hill, 2003) "By analyzing trading volume, a technician could more easily detect whether a price movement represented true commitment." (Dormeier, 2011) In commodities markets, there is a "positive relationship between the trading volume of the large hedge funds and market volatility" (Gregoriou, Karavas, Lhabitant & Rouah, 2004). On the long-term profitability, the volume information seems to be a strong criterion. "Markets nearly always behave better technically when they are moving on higher volume. The lower the volume, the more unpredictable they become because it does not take as much volume." (Norris & Gaskill, 2011)

The trading volume information can also be used to fundament an exit decision. Some authors indicate to build an exit decision after a maximal volume interval, considering that many other investors are closing their investments in that specific interval for a particular and right reason. "Trading volume decreases as the (wedge) formation develops. This is an important condition because declining volume during up trends suggests a reduction in buying pressures." (Appel, 2005). An exit decision can be made "when volatility suddenly expands on high volume after a sustained trend." (Katz & McCormick, 2000)

The general idea is that the trading volume is essential information provided by the stock exchange that must be included in the trading or investment decisions to improve capital efficiency. The question is, how? Very disappointing answers to this question can be found in the literature papers using terms as <after an unprecedented volume value>, <proper trading volume value>, or <not enough volume> without presenting any substantial or coherent measurement method or a mathematical approach for trading volume information usage. Intentionally the citations of these terms were excluded from this paper. How to analyze the volume information in real-time? How to include this data into reliable investment decisions? How to integrate the trading volume information in algorithmic trading strategies? And how to automate a trading decision based on the trading volume information? All of these are questions this paper will answer.

3. Volume Cyclicality

There is a trading volume cyclicality in time in any market. This is the main hypothesis of this paper that will be confirmed or not by the results. By cyclicality, we understand that periods with increasing and decreasing volume values can be clearly identified. On a low volume values market, with the proper market conditions changes, more and more investors will add orders to the market, and the trading volume will be increased. Based on this natural human behavior, the market will begin to evolve with higher prices that will also attract more investors. This will conduct to a time period with a higher volume values on average, even the volume value from one day to another will also be discontinued and unstable. After a time when the market is evolving well, the current trend usually meets some maximal points accompanied by maximal trading volume values. Depending on the market conditions or on the economic or geopolitical news, the investor's appetite can be changed. Once the investors start to know that the market made a maximal point, in lack of positive news or in the presence of negative news, the traded volume starts to decrease, once that market becomes less attractive. A decreasing investment enthusiasm will produce a descending trading volume period for the market. After a while, once the negative economic factors are solved, positive aspects will increase the investment attractiveness for the market again, and the cycle will be repeated.

This paper proposes a mathematical model that can be used to analyze the volume cyclicality. An analytical function will be built in order to transform the unstable volume function into a continuous function with a cyclical behavior. This function will be in direct correlation with the trading volume values and will permit us to analyze the volume change. Minimal and maximal points will be clearly identified, and the analysis of ascending and descending periods of the Volume Cyclicality function will allow us in a precise manner to include the volume information into the trading decisions. Moreover, the introduced function can be computed in real-time and can be implemented in any automatic capital investment software system.

A reliable mathematical model to study the cyclical behavior of the price market was introduced in (Păuna & Lungu, 2018). This paper will apply the same model for trading volume information. The first step to build the volume cyclicality function is to use two moving averages of the trading volume. We will note with M_i and m_i the series values of two moving averages of trading volume, with different periods P and p. The index *i* denotes the time interval. If the P is the period of M_i, and p is the period of m_i, and $P > p$, than, on an ascending period of the trading volume, we will have $M_i < m_i$. On a descending volume period, the high period moving average we will have $M_i > m_i$.

The cyclical behavior of the trading volume can be assessed if we analyze the evolution of the two moving averages above. To do that, we will use a specific mathematical conform transformation between the normal trading volume space and a particular space limited into the interval [0;1]. On a specific n number of time intervals, the maximal and minimal distance between the two moving averages can be computed using:

$$min_i = \min_{k=i}^{i-n}\left(M_i - m_i\right) \text{ and } max_i = \max_{k=i}^{i-n}\left(M_i - m_i\right) \quad (1)$$

The transformation mentioned above is built using:

$$\Delta_i = \frac{max_i - \xi_i}{max_i - min_i} \text{ where } \xi_i = M_i - m_i \quad (2)$$

In order to build the function that will describe the Volume Cyclicality, we will use a first-order Spline functions (Berbente, Mitran & Zancu, 1997) given by:

$$VOC_i = \alpha\left(\Delta_i - VOC_{i-1}\right) + VOC_{i-1} \text{ where } VOC_0 = 0 \quad (3)$$

The Volume Cyclicality function obtained with formulas (1), (2), and (3) for $n = 10$, $p = 10$, $P = 30$, and $\alpha = 0.33$ is drawn in figure 1.C. The functional parameter α determines the gradient of the *VOC* function, and can be optimized for each traded market. In figure 1.B., over the volume function drawn with bars is represented the moving average of trading volume with period $p = 10$.

As can be seen in figure 1, the Volume Cyclicality function is a periodic one. This fact confirms the hypothesis made, according to that the trading volume has a cyclical behavior. The *VOC* function has minimal and maximal points and clear ascending and descending periods, and it is computed using only the volume information. The price quotes are not used in this model.

The parameter values used above are, of course, an example. The *VOC* function can be built for any market with the proper parameters set in order to obtain the maximal efficiency and the minimally involved risk. The optimal parameter set can be found for each case using the historical volume series of the traded market and an optimization method. The author uses the gradient method (Berbente, Mitran & Zancu, 1997) to complete this step.

An important note about the *VOC* function is that the model can be built using the trading volume of any time period. In figure 1 is represented the Volume Cycaliclity using the daily time volume series, but M_i and m_i moving averages can be computed using the volume values for other intervals. Relevant studies can be found using one-hour (H1), four-hours (H4), and even one-week (W1) volume series data. In these cases, the *VOC* function is given by unchanged formulas (1), (2), and (3).

The cyclicality of the *VOC* function has different analysis criteria than *PCY* function (Price Cycaliclity Function). An increasing *VOC* period will determine a strong price evolution, but this is not meaning that the price will go up. Also, a descending price trend can be accompanied by an ascending *VOC* period. Usually, the *VOC* is ascending when more participants are joining the markets, and more buy and sell orders are substantially increasing the trading volume. A descending period of the *VOC* function denotes a small investment interest.

After a stable price trend, a maximal VOC point can indicate a change in investor behavior. That can be assimilated with an exit opportunity. Moreover, after a descending VOC period, a minimal point will occur. This will indicate an increase in the investors' interest in the current market and can be confirmed with a low-risk entry signal. Usually, after a minimal VOC point, a new trend is defined, a pattern that can also exist in both directions (upward or downward).

A particular interest is shown for a special pattern of thinking from the investment point of view. After a price downward trend, any investor searches for an answer to the question when that trend is over, and the price will be bottom out. The VOC function gives us this information in an exact manner. After a clear price downward trend the VOC function will make a minimal point and will start to ascend. That is one of the lowest risk signals that can be found. Investment results will be presented in the next section.

Figure 1 presents the evolution of the DAX30 index during the pandemic Coronavirus crisis in 2020. This choice is not accidental. The DAX30 decreased as never before in history, by 42.24%, from the maximal 13796 Euro on 17th February 2020 to the minimal value of 7968 Euro on 19th March 2020. During this unprecedented crash, any investor asks the question of when the market will stop falling and start to recover, and when it will be a safe point to start to buy. This moment is clearly defined by the Volume Cycaliclity function in figure 1. On 6th April 2020, the VOC function starts to ascend, and the market begins to recover, confirmed by the future evolution. Remember that the VOC function is built only based on the volume information; the price quotes are not included in the VOC computation formulas.

The Volume Cyclicality function is tested by the author starting with December 2010 on all equities included in the most important stock exchanges in the world: Frankfurt Stock Exchange 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), NASDAQ Index (NASDAQ100), Standard & Poor's Index (S&P500), and Small Capitalization US Index (Russell2000). A clustering method in time price series was used in two parallel ways for this purpose. In the first case, a cross-validation optimization method was tested with the historical price series of all mentioned stock exchanges. After the clustering validation, a real capital test was performed using periods of two months back in the time price series to generate real investment signals for one month further. All results obtained in the above capital markets are similar to the results presented in this paper. The Volume Cyclicality Method has been included in live trading since August 2011 through DaxTrader (Păuna, 2010) software included in theServer automated capital investment system.

Computing the Pearson correlation coefficient (Andrei, 2003) for all these markets, it was found that there is a strong and direct correlation between the minimal points of the VOC function and a stable and precise price movement in the ascending interval of the VOC function. The values of the computed correlation coefficient are situated between 0.712 and 0.862 for the study made on the 4-hours timeframe, and between 0.833 and 0.951 in the study processed with the daily timeframe data series. The results indicate a strong correlation that can be successfully used to build reliable capital investment signals, as it will be presented in the next section.

4. Investment signals with Volume Cyclicality

This chapter will answer the question of how to build capital investment signals using the Volume Cyclicality function? As it was already presented, the logic behind the usage of the VOC function is based on the idea that in an uncertain period, the investor's interest is

decreasing, producing a decrease in the invested volume and, by consequence, a decreasing period for the VOC function. When proper market conditions appear, the investors will start to add more and more orders onto the market, producing a volume increase. This fact will produce a minimal point for the VOC function, a specific point after the VOC evolution will have an increasing period. With the strong correlation between the minimal point of the VOC function and the stable evolution of the price in the ascending period, we can build a buy signal:

$$BuySignal_i = \left(VOC_{i-2} > VOC_{i-1}\right) \wedge \left(VOC_{i-1} < VOC_i\right) \quad (4)$$

Practically, the signals built with the formula (4) will generate a buy entry in the market after a minimal VOC point. In the old fashion investments, the entry decision is usually made after a maximal value of the volume. It was found that many times, after a maximal point of the volume, the prices can be even lower for a small period of time. Even the minimal values of the VOC function have a slight lag when we compare with the maximal volume point, and the practice proved that the entry price using the minimum VOC points, according to the signals (4) lower than the entries triggered by the maximal volume interval in many cases, this meaning that the VOC function will generate entries with a lower risk.

An important observation is that the formula (4) defined a BuySignal. We have mentioned before that after a descending period of the VOC function, depending on the market conditions, the price will register a stable evolution. This evolution is not necessary to be considered as price growth. Depending on the fundamental market conditions, the price quotes can also start a descending trend. The formula (4) was defined as BuySignal thinking that, after a representative descending price period, a price increase is more probable. On the analyzed markets mentioned above, the statistics showed us a probability of 1:30 chances as after a descending price trend, a new descending price trend to follow after a minimal VOC point, built with the daily time price series.

Figure 2 presents the capital evolution due to the signals (4) applied to the Frankfurt Deutscher Aktienindex DAX30 between 20.04.2019 and 19.04.2020 using the daily time price series. The trades were executed using DaxEqualizer software included in theServer automated capital investment system (Păuna, 2010). The risk management was made using the "Global Stop Loss" method (Păuna, 2018) with a global risk level of 1% of the current capital.

The signals (4) have generated 149 trades in the period mentioned above, with only five losing trades. These losing trades were made in those cases when after a descending period of the VOC function, a descending price trend was met. The entry signals made with (4) were built with no other price evolution condition. Using only the trading volume information, it was

obtained in this case, a risk to reward ratio of 1:2.08, meaning each 1 Euro risk has produced a profit of 2.08 Euro.

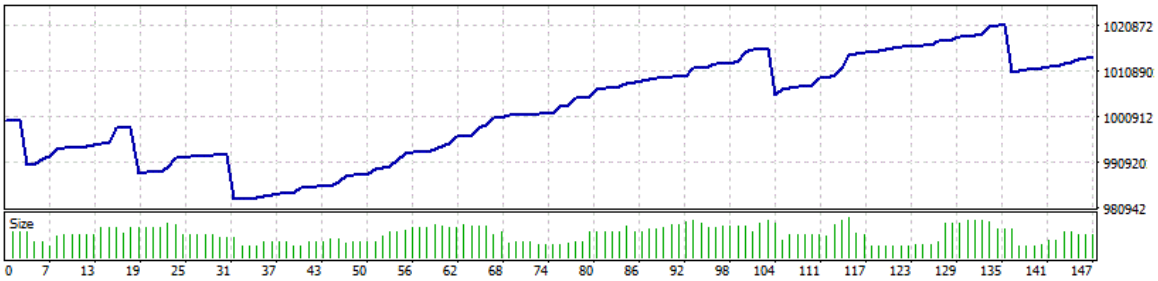

Figure 2: Capital evolution due to buy signals made with Volume Cyclicality

5. Investment signals with Volume Cyclicality and Price Cyclicality

The VOC function does not include information about the price direction; it is computed only on the trading volume information. The first optimization idea is to combine the signals provided by the minimal VOC points with some market conditions that will filter only those cases when the price registers an upward trend. This way, an investment signal will avoid the cases that produced losses in the example presented in the previous section.

During this time, more price-related conditions are tested to filter the VOC signals. Good results are obtained using the monotony of an exponential or weighted price moving average (Cox, 1961) or the Relative Strength Index (Wilder, 1978). Each of these additional price conditions was filtering the losing trades, but a significant number of winning trades from the example above were also excluded.

The best solution was found by using the Price Cyclicality function (Păuna & Lungu, 2018). The ascending periods of the PCY function are in a strong and direct correlation with the price evolution, as the authors proved in the introduction paper of the Price Cyclicality model. Combining the ascending periods of the VOC function with the ascending periods of the PCY function, the signals can be automated using the formula:

$$BuySignal_i = \left(VOC_{i-2} > VOC_{i-1}\right) \wedge \left(VOC_{i-1} < VOC_i\right) \wedge \left(PCY_i > PCY_{i-1}\right) \quad (5)$$

The asymptotic evolution of the PCY function is giving us the possibility to impose additional conditions in order not to enter in the market near a maximal price level. To avoid these cases,

the signals will include a limitation condition, meaning that the PCY function not to exceed a specific limit value:

$$BuySignal_i = (VOC_{i-2} > VOC_{i-1}) \wedge (VOC_{i-1} < VOC_i) \wedge (PCY_i > PCY_{i-1}) \wedge (PCY < \xi) \quad (6)$$

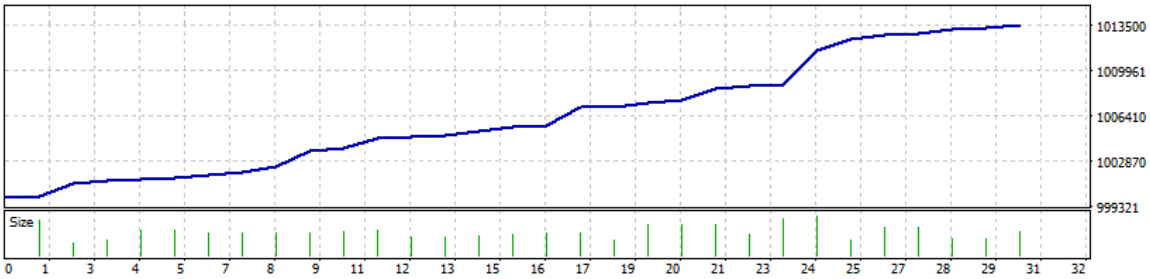

Figure 3. Capital evolution due to buy signals made with Volume Cyclicality and Price Cyclicality

In figure 3, is plotted the capital evolution due to the signals (6) applied for DAX30 between 20.04.2019 and 19.04.2020 using the daily time price series and the same traded volumes as in the case presented in the previous section. As can be observed, the number of trades is significantly lower. Also, the net profit recorded is lower due to this fact, but the capital drawdown, in this case, was three times less than the case above. Using the signals made by formula (6), it was obtained a risk to reward ratio of 1:4.62.

The signals (4), (5), and (6) were written for capital investment systems. On these particular strategies, after entry on the market is made, the position is kept open a long period of time until the market conditions dictate an exit decision. The investment strategies make a reduced number of trades and try to produce a higher profit on each position. The method of using the trading volume information can also be included in high-frequency trading systems. These strategies make a significantly higher number of trades and produce a small profit for each position. The signals (6) especially adapted for high-frequency trading systems will be built with the formula:

$$BuySignal_i = (VOC_{i-1} < VOC_i) \wedge (PCY_i > PCY_{i-1}) \wedge (PCY < \xi) \quad (7)$$

A significant improvement can be made imposing an additional limitation condition in the VOC value. It is well known that, after an extended price trend, when the price is approaching the maximal values, the volume starts to decrease, a fact that produces a reduction in the VOC function gradient before the maximal point. To avoid the case to entry in the market when the volume starts to decrease significantly, the buy signals will be made using the formula:

$$BuySignal_i = (VOC_{i-1} < VOC_i) \wedge (PCY_i > PCY_{i-1}) \wedge (PCY < \xi) \wedge (VOC < \lambda) \quad (8)$$

The ξ and λ parameters are at the technical analyst disposal. These functional parameters will be optimized for each traded market using the historical price and volume series to maximize profitability and to increase capital efficiency. Due to the large market volatility and fast-changing economic and geopolitical conditions, it was observed that the optimal parameters are changing for all markets from time to time. A machine-learning procedure that will adapt the optimal functional parameters periodically to the new market conditions will significantly improve the results.

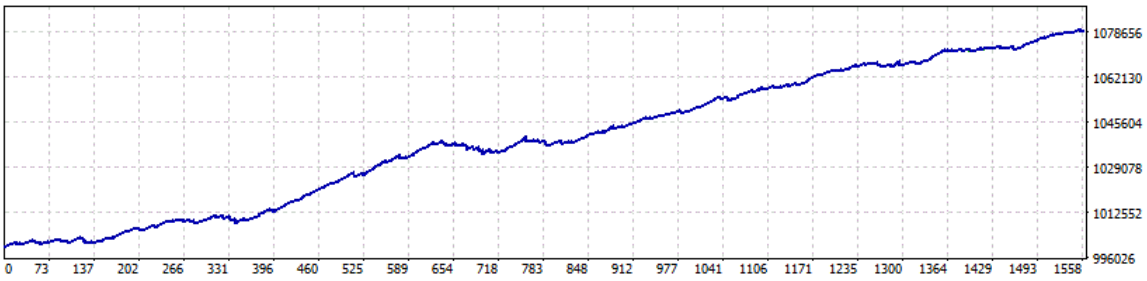

Figure 4. Capital evolution made with Volume Cyclicality and Price Cyclicality in high-frequency trading

The results presented in figure 4 are obtained using the trading signals made by formula (8) in high-frequency trading of DAX30 index between 20.04.2019 and 19.04.2020. Risk management was the same as in the examples above. The results were obtained using DaxRazor trading software included in theServer automated capital investment system (Păuna, 2010). The risk to reward ratio obtained in this case has a remarkable value of 1:7.66. Excluding the commissions, spreads, and taxes paid for all 1575 trades executed, the net risk to reward ratio obtained has a value of 1:6.82.

The signals presented in this paper can be combined with any exit strategy. The exit decisions can also include conditions in VOC function values, similarly with those included in the formula (8). The theory of the exit decisions optimized for each type of market entry is not a subject of this paper. Still, the right choice for closing the opened trades has a significant impact on capital efficiency.

6. Conclusions

The trading volume has a periodical evolution in time in all studied markets. The periodicity is variable in time and can be analyzed using the Volume Cyclicality function introduced in this paper. This function can be computed in real-time and uses only the trading volume

information. The minimal points of the VOC function have particular importance; after a minimum point, the function is making an ascending interval when the investor's interest is increased. This will produce an essential and strong price movement compared to the descending periods of the VOC function. Identifying the minimal point of the VOC function can provide a reliable capital investment signal to entry in the markets. Once the VOC function does not include any information about the price direction, the VOC trading conditions can be assembled together with additional price-related conditions.

The questions raised at the beginning in this paper have been answered: How should the volume information be analyzed in real-time? By studying the VOC functions periodicity to find the minimal and maximal points and to define the ascending and descending periods. How should trading volume information data be included into reliable investment decisions? Trading volume information is generating the time values of the VOC function, which is used to build real-time trading signals. How should the trading volume information be integrated in algorithmic trading strategies? By using VOC function together with PCY function to limit the functionality of any strategy, as presented. And how should a trading decision be automated based on the trading volume information? By building signals similarly with those shown in the 5th section, including the VOC and PCY functions as efficiency filters.

The combination of the Volume Cyclicality and Price Cyclicality functions gives us an outstanding risk to reward ratio. The volume information can also be included in the high-frequency trading systems using the ascending periods of the VOC function. The model presented in this paper can be automated and included in any trading or investment software system. Also, the Volume Cyclicality function can be used with excellent results for capital investment decisions made by human analysts.

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