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Alternative Prices Under Markowitz's Portfolio Model for FOREX Transactions

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Abstract:

Purpose: *In Markowitz's traditional portfolio analysis, only the close price is used to build an investment portfolio. This type of price is commonly regarded as an axiom. As such, this article aims to prove that the close price is not the best type of price. Using the close price means that a portfolio which appears optimal is far from it. Under certain assumptions, it can be demonstrated that the close price should not be used.*
Design/Methodology/Approach: *For the purposes of this study, 20 currency pairs were selected for analysis, from which portfolios of two assets were created. However, the best portfolios were additionally selected based on three "research spaces", five moving average lengths, and seven types of prices (including the close price). A total of 13,300 different portfolios of two assets were created. All portfolios were calculated using real Forex data. The author created an original subroutine for the MetaTrader4 trading platform to build this enormous number of portfolios. It enabled online data collection and calculation of the entire portfolio population. A time frame of 15 minutes (M15) was used for this purpose.*
Findings: *Thanks to such a large research sample, it was proven that the close price is not the best for building an investment portfolio. Within six hours, one of the prices gave an actual result that was 11,133.3% higher than that for the portfolio with the close price. This study proved the following hypotheses: "Selecting an optimal portfolio (in the traditional sense) using the close price is not an optimal solution", and "The close price is not the best price for building an investment portfolio."*
Practical Implications: *Empirically verified knowledge about the use of different types of prices may prove useful for all (investment companies, investors, researchers, students) who have so far only used the close price.*
Originality/Value: *No one has yet combined statistical knowledge, portfolio analysis, and MetaTrader4 trading platform software with an M15 time frame. No other studies using portfolio analysis question the axiom of using the close price in any market (including the Forex market).*

Keywords: *Portfolio choice, portfolio analysis, optimal portfolio, Markowitz, close price, Forex.*

JEL codes: *G11, G17.*
Paper Type: *Original research study.*

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1. Introduction

Trading in financial assets involves risk as well as return (Gautami *et al.,* 2022; Laws, 2018; Elton *et al.,* 2014; Rani, 2012; Haugen, 1993). Various analyses are helpful in this regard, including three basic types, fundamental analysis, portfolio analysis and technical analysis (Bednarz, 2023). Each type is well described in the literature (Eugster and Uhl, 2023; Moura and Neves, 2024; Hidayat and Hendrawan, 2017; Sharma and Mehra, 2017; Schwager, 2017; Bulkowski, 2012; Murphy, 1999; Greig, 1992).

Therefore, their detailed description will not be included here. However, due to the close link between this article and portfolio analysis, it should be noted that portfolio analysis helps to reduce investment risk. This is done by introducing an additional financial instrument into the portfolio, which reduces or eliminates specific risk (Quiry, 2011).

Such an approach to investing makes use of advanced statistical methods. The model in question was developed by Nobel Prize winner Harry Markowitz (Markowitz, 1952; 1959). Portfolio analysis answers the question of HOW to diversify investment risk.

The starting point in portfolio analysis is price, which is used to calculate rates of return. The next stages of portfolio construction involve calculations covering the variance of asset returns, standard deviation of asset returns, correlation coefficients of asset returns, and covariance of asset returns (...). The close price is always used as the starting point, or rates of return are used without specifying the price applied to calculate them. One may even argue that the close price is an axiom.

Accordingly, this article questions the exclusivity of the close price in building an investment portfolio. The author believes that the close price is not the only price that can be used in portfolio analysis. Moreover, its use means that a portfolio which appears optimal is far from it. This is proven by a study conducted on a sample of 13,300 investment portfolios in the rapidly evolving Forex market.

Consequently, a different price than the close price offers a better investment portfolio. This trading approach is also suitable for speculation (Bednarz, 2024; 2023). It can be argued that “A portfolio is a mixture of securities such as stocks, bonds and other money market instruments” (Gautami *et al.,* 2022). In the opinion of the author of this article, portfolio analysis is not limited to the money market. It can also be successfully applied to other markets, including Forex.

2. Literature Review

In the literature, it is difficult to find studies that use a price other than the close price to build an investment portfolio (Sen and Dasgupta, 2024; Ioannidis *et al.,* 2023; Syahrini *et al.,* 2023; Puri and Yadav, 2019; Sharma and Mehra, 2017). Some studies do not even disclose the price used to calculate the rates of return (which are the starting point for portfolio analysis).

In such cases, it can be assumed that it is the close price (Hiller, 2025; Palma *et al.,* 2024; Mohan and Thomas, 2023). Whether researchers use the close price or neglect to mention which price they use in their analyses, it is worth referring to studies that relate to Markowitz's portfolio analysis or the selection of an optimal portfolio.

Following the traditional Markowitz model, some of them aim "to limit the extent of short positions within the portfolio" (Candes and Plan, 2009). Others build portfolios "using weighted elastic net penalization" (Ho *et al.,* 2015). There are also studies dealing with "the cardinality constrained portfolio selection" (Gao and Li, 2013). Further, some studies use algorithms to construct optimal portfolios (Gao and Li, 2013; Brodie *et al.,* 2009). Then, there is the Adaptive Support Split-Bregman approach (Ho *et al.,* 2015).

Other interesting concepts include the Hyperbolic Absolute Risk Aversion (HARA) (Loukeris *et al.,* 2025) and the Optimal Portfolio Selection Intelligence (OPSI) (Loukeris and Eleftheriadis, 2016). Another solution is the lexicographic goal programming method (Syahrini *et al.,* 2023). The literature also includes studies aimed at detecting multiple optima of portfolio optimization (Qi *et al.,* 2018).

A noteworthy approach to investment portfolio optimization is the use of the genetic algorithm (GA) (Radak *et al.,* 2024). Some studies employ financial analysis (FA) in optimal portfolio selection (Sharma and Mehra, 2017). There are also compilations where "the application of Markowitz portfolio and Black–Litterman models is extended to energy portfolio selection in transmission-distribution environments with high penetration of renewable energy" (Mohan *et al.,* 2023). While intriguing, the above concepts of investment portfolio optimization may prove too sophisticated and difficult to apply in practice for many investors.

3. Methodology and Hypotheses

The close price is one of seven types of prices that can be used in financial markets. As such, it is not the only price that can be used in portfolio analysis. Indeed, its use means that a portfolio which appears optimal is far from it. To reach this conclusion, the author conducted extensive research involving the construction of 13,300 different portfolios of two assets[2] based on Markowitz's methodology (Markowitz, 1959; 1952). To that end, the following were selected for the study: a) Assets, b)

[2]*This study also examines a portfolio of three assets (Maccheroni et al., 2013), a portfolio of four assets (Laws, 2018), a portfolio of five assets (Syahrini et al., 2023), and a multi-asset portfolio (Laws, 2018).*

"Research spaces", c) Moving average lengths, d) Time frames, and e) Different types of prices.

3.1 Assets

Twenty low-spread currency pairs (on the Forex market) were selected for analysis. The low spread is a key criterion because Forex quotes are displayed as (line, bar, or candlestick) charts for the BID price only. The ASK price (used to open long positions and close short positions) is not displayed. Therefore, currency pairs with low spreads (as low as zero for EURUSD or 0.1 pips for AUDUSD, USDJPY, GBPUSD and many others) were selected to simplify calculations.

The following currency pairs were used to build the portfolios of two assets: AUDUSD, EURUSD, GBPUSD, NZDUSD, USDCAD, USDCHF, USDJPY, USDPLN, USDRON, AUDCAD, AUDCHF, AUDJPY, CADCHF, CADJPY, EURCAD, EURGBP, EURJPY, NZDCAD, NZDCHF, NZDJPY.

These 20 currency pairs can be used to build 190 different portfolios of two assets. The selection of assets is restricted to only 20 currency pairs due to limited data readability. For example, Table 1 is scaled to fit a typical computer screen. Above the diagonal, standard deviations for 190 portfolios of two assets are shown; below the diagonal, there are 190 expected returns for the same 190 portfolios constructed from those 20 currency pairs.

The introduction of one more currency pair (21 currency pairs in total) increases the number of results above and below the diagonal to 210 (an increase of 20 results above and 20 results below the diagonal). However, the introduction of eight additional currency pairs (28 currency pairs in total) means that there will be 378 results above and below the diagonal (compared to 190 at present).

Such an increase in the number of currency pairs is counterproductive and impairs the readability of the results. For this reason, the author has limited the number of currency pairs to 20.

3.2 "Research Spaces"[3]

The next area of research is the selection of "spaces", which are described as follows:

- "Space A"

[3] *"Research space" is a conventional term the author uses to refer to a specific feature directly resulting from Markowitz's portfolio analysis or directly related to it. In other words, a "research space" is a "research area" or "selection criterion" that distinguishes it from other relevant "research spaces". All "research spaces" are related to each other, like the X and Y coordinates in one coordinate system.*

This "space" encompasses the risk and expected return of all portfolios (efficient frontier), of which only one portfolio ranks highest. Each of these portfolios has its own specific "coordinates". These are risk σ (standard deviation, X coordinate) and expected return r (expected value, Y coordinate). This is shown in Table 1, where values above the diagonal represent risk (σ) and values below the diagonal represent the expected return (r). For portfolio 6_7 (USDCHF_USDJPY), σ = 0.037 %, r = 0.025 %.

Thus, "Space A" allows investors to select a portfolio that offers the highest rate of return for a given level of risk, measured by standard deviation. This is referred to as an "efficient portfolio" (Adler *et al.,* 2024; Laws, 2018; Elton *et al.,* 2014; Rani, 2012; Haugen, 1993) located at the highest point on the "efficient frontier" (Adler *et al.,* 2024; Mohan and Thomas, 2023; Laws, 2018; Elton *et al.,* 2014; Haugen, 1993) in the upper half of the Markowitz bullet (Haugen, 1993).

The portfolio was selected each time using a chart. For example, Figure 1 shows the optimal portfolio: Portfolio 6_7 (USDCHF_USDJPY, Portfolio 1, Table 3). A total of 35 such charts were created in the course of this study. Each presented 190 portfolios, yielding a total of 6,650 portfolios of two assets used for analysis.

- "Space B"
  This area of research refers to selecting a portfolio in which the correlation between assets (ρ) is close to zero. This ensures that changes in one currency pair do not cause significant changes in the other. If the compared portfolios had the same correlation coefficient (ρ), the portfolio with the lower coefficient of variation (coefficient of variation = σ / r) was selected.

  The choice of portfolio was made using a table each time. For example, Table 2 shows that the correlation coefficient closest to zero among the 190 portfolios (correlation coefficients are shown above the diagonal) is 0.012 for portfolio 9_10 (USDRON_AUDCAD, Portfolio 36, Table 4). A total of 35 such tables were created in the course of this study. Each table presented 190 portfolios, yielding a total of 6,650 portfolios of two assets used for analysis.

- "Space C"
  This area of research concerns selecting a portfolio with minimal standard deviation. This is referred to as the minimum variance portfolio (MVP) (Laws, 2018; Haugen, 1993), i.e. one with the lowest possible risk. The details of the portfolio selection are shown in Table 1, where the values above the diagonal are risk (σ). For portfolio 13_16 (CADCHF_EURGBP, Portfolio 71, Table 5), σ = 0.003 %. A total of 35 portfolios were created and selected from 6,650 others based on the MVP criterion.

  At this point, it is important to note that the values given above for Portfolios 6_7, 9_10 and 13_16 are results only for:

- one of the three “research spaces” (A, B, C),
- one of the five moving average lengths (4, 8, 12, 20, 24),
- one of the seven different prices (close, open, high, low, median, typical, weighted close).

Ultimately, 105 portfolios were selected for further analysis (3 x 5 x 7), each of which was always the best out of 190. As a result, a total of 19,950 portfolios of two assets (105 x 190) were analysed, all using a 15-minute (M15) time frame. It should be clarified here that the 6,650 portfolios later labelled “Space C” and “Space A” come from the same pool. However, the choice of the 35 portfolios for “Space C” was based on the MVP criterion (lowest possible risk), while the portfolios in “Space A” always had the highest risk with the maximum return. As such, these are different portfolios because the criteria for their selection were different. Accordingly, 19,950 portfolios were analysed, but 13,300 different portfolios were created.

3.3 Lengths of Moving Averages

The next element of this study was the moving averages with lengths of 4, 8, 12, 20, and 24 (Table 3, Table 4, Table 5 Column C). The returns calculated with these methods were used in statistical calculations, including variances and standard deviations for all currency pairs, covariances, correlation coefficients, portfolio asset weights, expected returns for all portfolios, and the variances and standard deviations of all portfolios following Markowitz’s traditional portfolio analysis.

The moving average lengths were not optimized; they were selected to be multiples of the 15-minute (M15) time frames used in this study. In the author’s opinion, if there is any regularity, then optimization is not required. Furthermore, with such a large sample of 13,300 different portfolios of two assets, optimization is unnecessary. The same moving average lengths (MA4, MA8, MA12, MA20, MA24) were used to evaluate the effectiveness of each of the 105 portfolios by comparing their actual results (Table 3, Table 4, Table 5, Columns M, N, O, P, Q).

3.4 Time Frame

Many studies use a time frame of “one month” to calculate the monthly returns (Adler *et al.,* 2024; Eugster and Uhl, 2023; Laws, 2018; Shipway, 2009). Others use a time frame of “one week” to calculate the weekly returns (Sharma and Mehra, 2017) or “one day” to calculate the daily returns (Puri and Yadav, 2019).

Nonetheless, in applying portfolio analysis to the Forex market, one cannot limit oneself to time frames such as “one month”, “one week”, or “one day”. The author believes that using such time frames is unreasonable in a rapidly changing market. It is more effective, and thus more profitable, to employ shorter time frames. Some studies suggest that the return on the Forex market can be as high as 132.7%

(Bednarz, 2023) within 10 trading days or 104% (Bednarz, 2024) within 44 hours when using the following time frames: H4, H1, M30, M15, M5 and M1. This article uses the M15 (15-minute) time frame to build investment portfolios.

The selection of this time frame was not optimized in any way, as the author believes that optimizing variables (in this case, the M15 time frame) for the hypotheses presented below (H1, H2) is contrary to a scientific approach to evaluating reality. If this study revealed any regularity, it is independent of the chosen time frame.

3.5 Different Types of Prices

The final element of this study was the use of seven different prices. In portfolio analysis, returns are commonly calculated using the close price. However, this is not the only option available. Many technical analysis programs (including MetaTrader4 or MetaTrader5 for trading on the Forex market) enable the user to choose between seven different types of prices. These include:

- Close Price [C]
- Open Price [O]
- High Price [H]
- Low Price [L]
- Median Price [(H + L) / 2]
- Typical Price [(H + L + C) / 3]
- Weighted Close Price [(H + L + C + C) / 4]

Therefore, limiting investment decisions to selecting a portfolio based solely on the close price means that such a portfolio may not necessarily be the best one. The results presented here indicate that this is the worst possible solution for selecting an optimal portfolio. Figure 2 describes where the basic prices (O, H, L, C) are placed on the bar chart showing the quotes.

3.6 Hypotheses

Ultimately, this article aims to show which of the seven types of prices is best for building the most efficient portfolio. This approach stems from the fact that the commonly used close price is not necessarily the best for building an investment portfolio. Therefore, this paper formulates two research hypotheses:

H1: *"Selecting an optimal portfolio (in the traditional sense) using the close price is not an optimal solution."*

H2: *"The close price is not the best price for building an investment portfolio."*

3.7 Data

The data for the calculations came from a Forex broker offering low spreads. This feature was decisive due to the widespread lack of data for the ASK price (the open price for a long position or the close price for a short position). Therefore, a low spread (even as low as 0 USD or tenths of a pip) makes it possible to use the BID price (the close price for a long position or the open price for a short position) without any significant error in the final results.

The BID price in files exported from Forex trading platforms is interpreted as the close price. The data for the study were generated from the MetaTrader4 trading platform, with an M15 time frame for 20 currency pairs. A subroutine for MetaTrader4 (a trading platform for the Forex market) developed by the author of this publication made it possible to perform calculations for all 13,300 different portfolios of two assets. The compilation of results for each of the 105 portfolios meeting all criteria (described below as “Space A”, “Space B”, and “Space C”) was prepared as a spreadsheet.

The period covered by the analysis includes M15 data until 21.00 on 6 February 2025. This means all portfolios were created at 21.00, and 105 portfolios were selected from these. This period was not “chosen to fit the hypotheses”. The author of this article reasons that if there is any regularity, it is independent of optimization.

The detailed evaluation of all 105 portfolios showed the actual performance of each portfolio starting at 22.00. Results (MA4) are given as the moving average of the four quote bars (time: 21.15, 21.30, 21.45, 22.00; Table 3, Table 4, Table 5 Column M). Similarly, results (MA8) are given as the moving average of eight bars (Column N), results (MA12) as the moving average of 12 bars (Column O), results (MA20) as the moving average of 20 bars (Column P), and results (MA24) as the moving average of 24 bars (Column Q).

It was also assumed that for each of the 105 portfolios, the investor has USD 10,000 at their disposal, of which only 40% will be allocated to investment in a given portfolio (i.e., USD 4,000). This assumption is necessary due to the risk of capital falling below the required margin. In such a situation, the broker closes losing positions. Calculations related to swap points, which apply after the change of the trading date, were also omitted.

Their impact on the final results would depend on whether the position is long or short. For example, with a trading volume of 1 lot in the USDJPY currency pair, a long position generates an additional profit of +USD 24.42 in swap points, while a short position results in a loss of –USD 40.60. For the USDPLN pair, swap points result in a loss of –USD 19.43, regardless of whether the position is long or short. For the USDCAD currency pair, a long position represents a profit of +USD 1.76, while a short position represents a loss of –USD 5.27.

Due to the significant variability in these additional gains or losses, swap points were deliberately omitted from the analysis. Moreover, portfolio evaluations were conducted after one hour (MA4, four time frames, time: 21.00–21.59.59), two hours (MA8, eight time frames, time: 21.00–22.59.59), and three hours (MA12, twelve time frames, time: 21.00–23.59.59).

In each scenario, the trading date remained unchanged, thus eliminating gains or losses arising from swap points. The brokerage commissions, which for the 1 lot position are equivalent to USD 7 for each currency pair, were also omitted. A leverage of 50:1 is used for all calculations.

Thirteen different calculations are required to calculate the risk and expected return for just one portfolio. The results included in Table 1 alone required as many as 2,470 calculations (13 x 190 portfolios). Table 2 additionally presents the results of calculations necessary to select the best portfolio, which must include the expected return r (Column A) and the standard deviation of the return σ (Column B) for each asset.

In order to calculate the actual results for each of the 105 portfolios, it is necessary to know the value of 1 pip in USD (Column C) and the value of the margin requirement in USD (Column D). Table 2 also contains correlation coefficients (ρ, values above the diagonal) and the weight of one asset in each constructed portfolio (X_A, values below the diagonal).

Due to the enormous number of calculations and portfolios analysed, only those portfolios (105 out of a total of 19,950) that are consistent with "Space A" (Table 3), "Space B" (Table 4) and "Space C" (Table 5) are presented. For comparison, the performance of all 105 portfolios is presented using the average results (in USD) achieved on each portfolio (Columns M, N, O, P, Q).

Each time, it is a moving average that includes 4, 8, 12, 20 and 24 quote bars. Each bar covers 15 minutes (M15). Therefore, these are average, actual results covering a period from 1 hour (4 x M15) to 6 hours (24 x M15) after the creation of each portfolio.

According to this explanation, the average result calculated from 4 M15 bars (Column M) for Portfolio 1 (Table 3, Close price, Portfolio 6_7, USDCHF_USDJPY, "Space A") is USD 55.8. However, the average result calculated from 24 M15 bars (Column Q) is USD 53.8. For Portfolio 36 (Table 4, Close price, Portfolio 9_10, USDRON_AUDCAD, "Space B"), the average result calculated from 4 M15 bars (Column M) is USD 25.0.

Yet, the average result calculated from 24 M15 bars (Column Q) is –USD 0.6. For Portfolio 71 (Table 5, Close price, Portfolio 13_16, CADCHF_EURGBP, "Space C"), the average result calculated from 4 M15 bars (Column M) is USD 47.5. Still, the average result calculated from 24 M15 bars (Column Q) is USD 76.1. The results are calculated “on the bars”, following the bar on which “all portfolios were built” (at 21.00). This makes it possible to assess the impact of the close price (and other types of prices) used on actual results (in USD).

Referring to returns is a better way to show the profitability of each price type. The author of this article chose not to include this due to the need for additional calculations involving the conversion of portfolio asset weights (X_A and X_B; Tables 3, 4, and 5, Columns H and I) into position sizes expressed in lots, adjusted for the margin requirements of the respective currency pairs (Table 2, Column D).

This is omitted solely due to the limited space in this article.[4] The reference to the average realized profits/losses in USD provides an equally tangible measure of using prices other than the close price.

4. Research Results and Discussion

The research results are shown in Figure 3. The figure shows that although the close price is a viable option, there are better ones (e.g. high, typical, weighted).

In **“Space A”**, portfolio 6_7 (Figure 1) was not optimal (result: USD 55.8; MA4; portfolio No. 1, Table 3, Column M; Table 6, Column I) if the close price was used. The optimal portfolio was the one using the high price (portfolio No. 3; 5_12), whose result was 42.47% higher (USD 79.5; MA4; Table 3, Column M; Table 6, Column I).

Further, the use of the typical price enabled a 24.45% higher result than for the close price, amounting to USD 70 (portfolio No. 6; 6_12; MA4; Table 3, Column M; Table 6, Column I). The weighted price also yielded a result that was 23.48% better than the close price of USD 68.9 (portfolio No. 7; 6_20; MA4; Table 3, Column M; Table 6, Column I).

In **“Space B”** (correlation coefficient between assets close to zero), the close price is almost the worst possible choice (USD 57.1). Only the weighted price achieved an inferior result. The best result with the low price (USD 78.9) was 38.18% higher than the close price. Comparing the results obtained with the same average in the MA4 portfolio (as in “Space A”), but with a longer portfolio holding time of 6 hours, MA24 for actual results (Table 4, Column Q), it can be seen that the close price is the least favourable choice. The high price was 1,1133.3% better than the close price, and the low price was 7,166.67% better (Table 4, Column Q).

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[4]*Naturally, all asset weights in the portfolios (X_A and X_B) were recalculated relative to the respective margin requirements and are incorporated into the results presented in Tables 3, 4, and 5 (Columns M, N, O, P, Q).*

In **"Space C"** (lowest possible risk σ, MVP portfolio), using the close price is not terrible, but the typical price proved to be 9.33% better, and the high price was 2.89% better. Comparing the results obtained with the same average in the MA4 portfolio (as in "Space A" and "Space B"), it is worth noting that those for the typical price (portfolio No. 76, Table 5, Column M) were 74.11% better than for the close price. Figure 3 compares the maximum results (regardless of whether a moving average with a length of 4 or any other was used).

Therefore, the results can be compared using the average calculated for the entire group of results for a given price. This is the average of 25 values (5 average lengths x 5 average lengths, Table 6, Table 7, Table 8 Column J). Then, the results are more straightforward. This is shown in Figure 4.

Figure 4 indicates that **the close price should not be used in "Space A".** The average result from 25 measurements was a loss of –USD 21.3. Other types of prices have an even worse average result. In contrast, all prices are suitable for use in "Space B" and "Space C". In "Space B", the average low price (USD 23.1) was 52.98% higher than the average close price (USD 15.1).

The average high price and the median price were also 36.42% higher than the average close price. In contrast, in "Space C", the average high price (USD 36.9) was 59.05% higher than the average close price (USD 23.2). For the typical price (USD 30.6), the result is 31.9 % higher.

5. Conclusions, Proposals, Recommendations

The study shows that prices other than the close price can be used when building an investment portfolio. The different returns obtained through them directly influence the composition of the investment portfolio. This paper shows that regardless of:

- the maximum value of the bar averages (Table 6, Table 7, Table 8, Column I; Figure 3),
- the average value for 25 measurements for one price type (Table 6, Table 7, Table 8, Column J; Figure 4), the close price will not create an optimal portfolio. Other types of prices make it possible to build better portfolios and achieve superior real results (in USD).

Therefore, ***H1:*** *"Selecting an optimal portfolio (in the traditional sense) using the close price is not an optimal solution" should be considered true. The consequence of proving H1 is to accept* ***H2:*** *"The close price is not the best price for building an investment portfolio."*

The proven hypotheses provide a new perspective on traditional portfolio analysis. The use of the close price no longer has to be an axiom. Actual results may be significantly better with other price types. On the other hand, these other types of prices enable the creation of more efficient portfolios. This approach is particularly recommended for investors whose acceptable risk level allows them to achieve higher real returns than the close price used so far.

References:

Adler, H.M., Nera, M.M., Sijabat, J., Manurung, A.2024. The construction of a portfolio using varying methods and the effects of variables on portfolio return. International Journal of Economics and Financial Issues, 14(1), 233-241. doi:https://doi.org/10.32479/ijefi.15314.

Bednarz, K. 2023. Klasyczny portfel Markowitza vs. portfel techniczny. Porównanie stóp zwrotu na rynku Forex. (Markowitz's Portfolio vs. Technical Portfolio. The Rates of Return Comparision on the Forex Market). Przegląd Prawno-Ekonomiczny, (4), 9-23. https://doi.org/10.31743/ppe.16664.

Bednarz, K. 2024. Portfel Markowitza w transakcjach na rynku Forex (Markovitz's portfolio In the Forex transactions). Bank i Kredyt 55(5), 603-622. https://bankikredyt.nbp.pl/content/2024/05/BIK_05_2024_03.pdf.

Brodie, J., Daubechies I., De Mol, C., Giannone, D., Loris, I. 2009. Sparse and stable Markowitz portfolios. Proceedings of the National Academy of Sciences, 106, 12267-12272.

Bulkowski, T.N. 2012. Fundamental analysis and position trading: Evolution of a trader. John Wiley & Sons, Incorporated.

Candes E., Plan Y. 2009. Near-ideal model selection by l1 minimization. Annals of Statistics, (37), 2145-2177.

Elton, E.J., Gruber, M.J., Brown, S.J., Goetzmann, W.N. 2014. Modern Portfolio Theory and Investment Analysis. 9th ed. United States: John Wiley & Sons.

Eugster, P., Uhl, M.W. 2023. Technical analysis: Novel insights on contrarian trading. European Financial Management, 29, 1160-1190. https://doi.org/10.1111/eufm.12389.

Gao, J., Li, D. 2013. Optimal cardinality constrained portfolio selection. Operations Research, (61), 745-761.

Gautami, S., Naik, B.S. Reddy, N.V. 2022. A study on construction of optimal portfolio for selected stocks using Sharpe's single index model. NeuroQuantology, 20(20), 46-58. doi:https://doi.org/10.48047/NQ.2022.20.20.NQ109007.

Greig, A.C. 1992. Fundamental analysis and subsequent stock returns. Journal of Accounting and Economics,15(2-3), 413-442

Haugen, R. 1993. Modern Investment Theory, 3th ed. United States: Prentice Hall.

Hidayat, F., Hendrawan, R. 2017. Stock portfolio analysis: Active and passive strategies formed with financial indicators. Journal of Economic & Management Perspectives, 11(3), 315-326. https://www.proquest.com/scholarly-journals/stock-portfolio-analysis-active-passive/docview/2101265066/se-2.

Hiller, T. 2025. Allocation of portfolio risk considering structures on assets: which is the best cooperation structure value to solve the low-risk anomaly? Applied Economics Letters, 1-8. https://doi.org/10.1080/13504851.2025.2473666.

Ho, M., Sun, Z., Xin, J. 2015. Weighted elastic net penalized mean-variance portfolio design and computation. SIAM Journal on Financial Mathematics, (6), 1220-1244.

Ioannidis, E., Sarikeisoglou, I., Angelidis, G. 2023. Portfolio construction: A network approach. Mathematics, 11(22), 4670. doi:https://doi.org/10.3390/math11224670.

Laws, J. 2018. Risk versus return. In Essentials of Financial Management (pp. 19-50). Liverpool University Press. http://www.jstor.org/stable/j.ctvt6rjjs.5.

Loukeris N., Eleftheriadis, I. 2016. The optimal portfolio selection intelligence (OPSI) model. In: World Finance Conference, July 29-31, New York, USA.

Loukeris, N., Eleftheriadis, I., Livanis, 2025. An Effective Investments System in the Optimal Portfolio Selection Intelligence (OPSI). Comput Economics. https://doi.org/10.1007/s10614-025-10854-y.

Maccheroni, F., Marinacci, M., Ruffino, D. 2013. Alpha as ambiguity: robust mean-variance portfolio analysis. Econometrica, 81, 1075-1113. https://doi.org/10.3982/ECTA9678open_in_new.

Markowitz, H.M. 1952. Portfolio selection. Journal of Finance, 7(5), 77-91.

Markowitz, H.M. 1959. Portfolio Selection: Efficient Diversification of Investments. New York: John Wiley Sons, pp. 95-112. (reprinted by Yale University Press, 1970, ISBN 978-0-300-01372-6; 2nd ed. Basil Blackwell, 1991, ISBN 978-1-55786-108-5).

Mohan, M,J., Mohan, V., Thomas, M.S. 2023. Risk-return optimised energy asset allocation in transmission-distribution system using tangency portfolio and Black–Litterman model. IET Energy System Integration, 5(3), 290-306. doi:https://doi.org/10.1049/esi2.12102.

Moura, M., Neves, R. 2024. Using fundamental analysis and an ensemble of classifier models along with a risk-off filter to select outperforming companies. Springer.

Murphy, J. 1999. Technical analysis of the financial markets: A comprehensive guide 827 to trading methods and applications. New York: Prentice Hall Press.

Palma, M.M., Carrillo, P.A.Á., Espinoza, E.L.M., Castro, E.L. 2024. A Multicriteria Approach to Integration and Evaluation of Investment Portfolios: The New York Stock Exchange. Innovar: Revista de Ciencias Administrativas y Sociales, 34(93), 1-26. https://www.jstor.org/stable/27367195.

Puri, Y., Yadav, A. 2019. Portfolio selection in NSE expected return & risk through markowitz portfolio theory. Management Dynamics, 19(2), 46-54. doi:https://doi.org/10.57198/2583-4932.1022.

Qi, Y., Wang, Z., Zhang, S. 2018. On analyzing and detecting multiple optima of port folio optimization. Journal of Industrial and Management Optimization, (14), 309-323.

Quiry, P., Le, F.Y., Salvi, A., Dallocchio, M., Le, F.Y. 2011. Frequently asked questions in corporate finance. John Wiley & Sons, Incorporated.

Radak, V., Damjanović, A., Rankovic, V., Drenovak, M. 2024. Mean-Expected Shortfall Portfolio Optimization Using A Genetic Algorithm. Ekonomski Horizonti, 26(2), 143-156. doi:https://doi.org/10.5937/ekonhor2402149R.

Rani, A. 2012. The modern portfolio theory as an investment decision tool. International Journal of Management Research and Reviews, 2(7), 1164-1172. Retrieved from: https://www.proquest.com/scholarly-journals/modern-portfolio-theory-as-investment-decision/docview/1417477899/se-2.

Schwager, J.D. 2017. A complete guide to the futures market: Technical analysis, trading systems, fundamental analysis, options, spreads, and trading principles. John Wiley & Sons.

Sen, J., Dasgupta, S. 2024. Portfolio Optimization: A Comparative Study. IntechOpen. doi: 10.5772/intechopen.112407.

Sharma, A., Mehra, A. 2017. Financial analysis based sectoral portfolio optimization under second order stochastic dominance. Annals of Operations Research, 256(1), 171-197. doi:https://doi.org/10.1007/s10479-015-2095-y.

Shipway, I. 2009. Modern portfolio theory. Trusts & Trustees, 15(2), 66-71. doi:https://doi.org/10.1093/tandt/ttn129.

Syahrini, I., Sardini, A., Nurmaulidar, N., Ikhwan, M. 2023. Application of lexicographic goal programming method on stock portfolio optimization with expected shortfall approach. TEM Journal, 12(3), 1390-1396. doi:https://doi.org/10.18421/TEM123-19.

Zou, H., Hastie, T. 2005. Regularization and variable selection via the elastic net. Journal of the Royal Statistical Society: Series B (Statistical Methodology), (67), 301-320.