SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 232

ANALYSIS OF SIGNAL ACCURACY FROM TECHNICAL INDICATORS FOR INVESTMENT IN GLOBAL STOCK MARKET INDICES

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Purpose: The article presents innovative technical analysis indicators, the so-called vanguard indicators, and compares their effectiveness with classic indicators and the "buy and hold" strategy based on the analysis of 63 global stock market indices. The aim of the study was to evaluate the accuracy of signals generated by selected technical analysis indicators in the context of investing in global stock market indices. The research utilized classic signals produced by chosen technical analysis indicators, as well as their opposite signals, referred to later in the article as newly developed "vanguard" indicators. The results of both strategies were then compared to the "buy and hold" strategy, representing a passive investment approach.
Design/methodology/approach: The database used in the study contained historical quotations of 63 global stock market indices from all continents, covering the period from the inception of each index up to December 31, 2023. Quantitative historical data analysis and statistical tests using Excel and the GRETL program were used.
The following classic technical analysis indicators were included in the study: RSI, CCI, W%R, DM, and ST. The study verified the following research hypotheses: H1: The application of an investment strategy utilizing the developed Vanguard Indicators is economically more advantageous than the use of existing Classic Indicators for major global stock market indices, H2: The application of an investment strategy utilizing the developed Vanguard Indicators is economically more advantageous than the use of the "Buy and Hold" Strategy for major global stock market indices, H3: The use of Vanguard Indicators demonstrates the highest accuracy regardless of geographical location.
Findings: The results showed that newly developed vanguard indicators generate statistically higher rates of return, especially outside America, where their effectiveness was comparable to the passive strategy. The study suggests that selecting the most effective indicator from the vanguard group for a given index allows to maximize profits.
Research limitations/implications: A limitation of the conducted research was the number of classic technical analysis indicators included in the study. The indicators were selected based on criteria that allowed for their values to be calculated using Microsoft Excel and an access to high-frequency data. One of the key limitations of the conducted study is also the omission of transaction costs, price slippage, and liquidity constraints, which may significantly affect the actual effectiveness of the analyzed investment strategies.

Practical implications: The research results can be used to shape the investment decisions for investors.
Originality/value: The literature contains a limited number of studies comparing the accuracy of technical analysis indicators across markets from different regions of the world; most research tends to focus on individual continents. Moreover, studies assessing the accuracy of indicators for index-based investments are typically based on short research periods spanning only a few or several years while overlooking many years of index existence, which also represents a research gap worth addressing.
Keywords: technical analysis indicators, global stock market indices, active investing, buy-and-hold strategy.
Category of the paper: research paper, conceptual paper.

1. Introduction

Investors have always sought tools to help them make informed investment decisions. One such tool is technical analysis indicators, which provide easy-to-interpret signals for initiating or terminating transactions. A common issue raised in the literature and observed in investment practice is the accuracy of these signals, as it impacts individual strategies and final investment outcomes. Technical analysis indicators are applicable in various markets. However, with the increasing popularity of ETF funds, it has become easier to invest in stock market indices, eliminating the need to create a composite basket of individual shares. Now, it only requires the purchase of specific participation units that represent the investor's index of interest (Mitrenga, 2013). Analyzing the accuracy of signals generated by technical analysis indicators, using stock market indices as an example, appears to be an essential issue from both investment theory and practice. This issue is rooted in two key economic theories: the theory of efficient markets, which posits that the prices of financial assets reflect all available information (Dobrowolski, 2014), and the theory of technical analysis, which assumes that prices move according to specific patterns known as trends (Paluszak, Wisniewska-Paluszak, 2018).

The article aims to assess the accuracy of signals generated by selected technical analysis indicators when investing in global stock market indices. The study utilizes classic signals generated by selected technical analysis indicators and opposing signals, referred to in the remainder of the article as "avant-garde." The results of both strategies were then compared to those of the buy-and-hold strategy, which represents a passive investment style.

Technical indicators yield variable signal accuracy across global stock market indices (Shynkevich et al., 2017). In the preliminary studies reviewed, Moving Average Convergence Divergence (MACD) appears in four analyses and Relative Strength Index (RSI) in three, while diverse moving averages and other indicators appear in individual reports (Anghel, 2015). Three studies report quantitative accuracy rates: a Random Forest model attained 80% accuracy on NASDAQ, and support vector machine approaches on the S&P 500 reached 75.4% to 82.6%

accuracy (Cervelló-Royo, Guijarro, 2020). Several papers note that optimized or combined indicators outperform standard parameter settings (Fayek et al., 2013). Key findings include:

- Emerging markets (such as indices in China, India, and Hong Kong) show stronger performance of technical analysis methods than some developed markets (Stavytskyi, Taraba, 2020).
- Developed market indices (e.g., the S&P 500 and FTSE) exhibit mixed results, with some studies noting high accuracy and others reporting poorer performance (Shynkevich et al., 2017).
- Short-term forecasts benefit from aligning data window lengths with forecast horizons, while long-term analyses indicate that parameter optimization improves investment return metrics (Shynkevich et al., 2017).

These results indicate that signal accuracy from technical indicators depends on the indicator chosen, the market context, and the analytical methods employed (Shynkevich et al., 2017).

The preliminary analysis of the literature revealed diverse research findings on the accuracy of technical indicators for indices from various geographic locations. The proposed study encompasses as many as 63 global stock market indices over the most extended possible period, from the beginning of each index to December 31, 2023, i.e., the last completed year when the research was initiated. The study was conducted using an MS Excel spreadsheet and the GRETL program, which was employed to perform statistical tests.

The following hypotheses were verified in the study:

- **H1**: An investment strategy employing the developed Avant-Garde Indicators is more economically advantageous than existing Classic Indicators for the leading world stock market indices.
- **H2**: An investment strategy employing the developed Avant-Garde Indicators is more economically advantageous than the Buy-and-Hold Strategy for the leading world stock market indices.
- **H3**: The use of Avant-Garde Indicators demonstrates the highest accuracy regardless of geographic location.

The article consists of seven sections. Section 1 is an introduction to the topic. Section 2 presents the individual technical analysis indicators used in the research, along with the method for interpreting the signals they generate. Section 3 contain sanoverview of previous studies on the accuracy of technical indicators for investments in stock market indices. Section 4 presents the adopted research methodology in detail. Section 5 discusses the research results. Section 6 offers conclusions and a discussion of the result sobtained by Rother researchers. The final section provide sinformation on the sources of financing for the article. The article concludes with a table that presents the exact list of global stock market indices examined.

2. Technical Analysis Indicators as Determinants of Trading Signals

Technical analysis is a method of forecasting the prices of financial instruments. It enables the prediction of future trends based on historical prices and trading volume (Murphy, 1999). Many techniques are employed in technical analysis, one of which is the use of indicators (Pilipchenko et al., 2021). A diverse range of designs characterizes technical analysis indicators. Some are calculated based solely on prices, while others are based on volumes. Due to the lengthy research period and the resulting availability of data, the study employed indicators that do not account for volume in their design. Oscillators often used by investors were employed, i.e., indicators that allow for the identification of oversold and overbought levels (Brown, 1999), such as Relative Strength Index (RSI), Commodity Channel Index (CCI), Williams Percent Range (W%R), DeMarker (DM), and Stochastic Oscillator (ST).

The Relative Strength Index (RSI) is an indicator created by Welles Wilder (1978) that compares the upward and downward movements of closing prices over a given period (see Formula 1).

$$RSI = 100 - \frac{100}{1+RS} \text{where} RS = \left(\frac{a}{b}\right) \quad (1)$$

where:

a – average value of the increase in closing prices in the analyzed period,

b – average value of the closing price decline for the analyzed period.

The indicator takes values from 0 to 100. Values above 70 (and, in the conservative variant, above 80) indicate that the market is overbought, signaling the opening of a short position or the closing of a long one. In turn, values below 30 (in the conservative variant below 20) indicate that the market is oversold, signaling the opening of a long position or the closing of a short one (Panigrahi et al., 2021).

The Commodity Channel Index, developed by Donald Lambert (1983), measures the difference between the current price and the average price for a given period (see Formula 2).

$$CCI = \frac{1}{0{,}015} * \frac{CT - SMA(CT)}{\sigma(CT)} \text{ where } CT = \frac{C_{max}+C_{min}+C_z}{3} \quad (2)$$

where:

CT – typical rate,

C_{max} – maximum rate,

C_{min} – minimum rate,

C_z – closing rate,

SMA – simple moving average,

σ– averages standard deviation.

The CCI does not have a strict range. Values below -100 indicate oversold conditions, signaling the opening of a long position or the closing of a short one. In contrast, values above 100 suggest overbought conditions, which signal taking a short position or closing a long one (Carroll, Fusilier, 1997).

Williams Percent Range (W%R) is an indicator by Larry Williams (1979). The indicator's value is obtained by calculating the quotient of the difference between the current closing price and the high price of *n* periods, and the difference between the high and low prices of *n* periods. The obtained result should then be multiplied by 100. Formula 3 presents the method of calculating the indicator.

$$\%R = \frac{C_z - C_{max}}{C_{max} - C_{min}} * 100 \tag{3}$$

where:

C_z – current closing rate,

C_{max} – maximum rate from n periods,

C_{min} – minimum rate from n periods.

The Williams Percent Range oscillator takes values from -100 to 0. Values close to -100 indicate an oversold zone, while values close to 0 indicate an overbought zone. A buy signal is generated when the oscillator takes values below -80, while a sell signal is generated when they are above -20 (Achelis, 2001).

The DeMarker (DM) indicator, developed by Tom DeMark (1994), compares the periods during which maximum prices are achieved within a selected time frame (see Formula 4).

$$DeM = \frac{SMA\ (DeMax,O)}{SMA(DeMax,O)+SMA\ (DeMin,O)};$$

where:

$DeMax = H\ (i) - H\ (i-1)$ if $H\ (i) > H\ (i-1)$ or

$DeMax = 0$; if $H\ (i) =< H\ (i-1)$ (14)

DeMin = L (i – 1) – L (i) if $L\ (i) < L\ (i-1)$,

DeMin = 0 if L (i) $>= L\ (i-1)$

where:

H (i) – maximum rate of the current period,

L (i) – minimum rate of the current period,

H (i – 1) – maximum rate of the previous period,

L (i – 1) – minimum rate of the previous period,

SMA - simple moving average,

O – number of periods for which the indicator value was calculated.

The oscillator takes values from 0 to 1. Values above 0.7 indicate an overbought market, signaling the potential for a short position or the need to close a long one. Values below 0.3 indicate an oversold market, signaling the opening of a long position or the closing of a short one (DeMark, 1997).

The Stochastic Oscillator developed by George Lane (1984) consists of two lines: %K and %D. The %K line is the main line of the oscillator, and the %D line is a three-period moving average of the %K line. Formula 5 presents the method for calculating the %K line of the Stochastic Oscillator.

$$ST = \frac{C_z - C_{min}}{C_{max} - C_{min}} * 100 \quad (5)$$

where:

C_z – current closing rate,

C_{max} – maximum rate from n periods,

C_{min} – minimum rate from n periods.

The %K and %D lines take values from 0 to 100. %K values above 0.9 indicate that the market is overbought, signaling the potential for a short position or the need to close a long one. On the other hand, values below 0.1 indicate that the market is oversold and signal the opening of a long position or the closing of a short one (Damayanti et al., 2020).

3. Literature Review on the Validity of Technical Indicators for Investing in Stock Market Indices

Many authors have addressed the problem of forecasting stock market index prices using technical indicators, and their research has referenced indices from various geographic locations. This research can be divided into two categories: those referring to European, American, and Asian indices, and those considering indices from other parts of the world.

Detry and Grégoire (2001), in their article, examined the accuracy of technical forecasts using moving averages for stock indices of fifteen European Union countries. Their research covered periods from the inception of specific indices (1965-1993) up to January 1, 1999. They demonstrated that even the most basic technical analysis tools, such as moving averages, enable accurate price forecasting of European stock indices. A similar study was conducted by Fifield, Power, and Sinclair (2005), who tested strategies based on moving averages for indices from eleven European countries in a similar research period (1991-2000). Their results indicated that rates of return on emerging markets (including Greece, Hungary, and Turkey) were characterized by greater predictability than on developed markets (including Germany, France, and the United Kingdom). A study analyzing the accuracy of forecasting the British FS30 index over sixty years was conducted by Chong and Ng (2008). However, MACD and RSI indicators were used to predict the index value in this case. Chong and Ng's results indicated that strategies based on both indicators allowed for obtaining higher rates of return than those resulting from the buy-and-hold strategy. In their research, Trembiński and Stawska

analyzed the accuracy of forecasting the German DAX index using six strategies constructed based on moving averages, oscillators, and trend indicators. They compared their results to those of the buy-and-hold strategy for data from 2015 to 2020. Of the six analyzed strategies, only the one based on the Ichimoku indicator yielded negative rates of return, assuming the worst possible outcome for the investment. At the end of 2019, four technical strategies outperformed the buy-and-hold strategy, and by the end of the first quarter of 2020, all of them had. Trembińska and Stawski (2021) also showed that during periods of increased volatility, technical strategies protected the portfolio against losses to a greater extent than the buy-and-hold strategy. Górska's article, which analyzed, among others, the prices of the WIG 20 Index and the raw material sector indices WIG Spożywczy, WIG Paliwa, and WIG Chemia in the period from March 2009 to July 2011, is relevant to the issue of the accuracy of forecasting stock market index prices using technical indicators (moving averages, oscillators, and the trend indicator – MACD) concerning the Polish market. The article was prepared by Górska (2011), who analyzed, among other things, the prices of the WIG 20 index and the raw material sector indices WIG Spożywczy, WIG Paliwa, and WIG Chemia during the period from March 2009 to July 2011. The buy-and-hold strategy yielded better results than those generated by technical strategies for each of the analyzed indices.

In studies on American stock market indices, the most frequently analyzed rates of return are the S&P 500 Index. Pistole and Metghalchi (2010) compared the accuracy of technical forecasts based on moving averages and the Parabolic SAR and RSI indicators in five-year and seventeen-year periods ending in April 2009. The rates of return generated using the indicators turned out to be higher than those for the buy-and-hold strategy. At the same time, the highest accuracy was achieved using the signals of the Parabolic SAR indicator. The statistical test results confirmed the strategy's statistical significance based on the Parabolic SAR indicator. Paik, Choi, and Vaquer (2024) analyzed the accuracy of signals generated by an algorithm based on indicators such as Williams %R, trading volume, and stochastic oscillator for the S&P 500 Index from 2010 to 2023. The algorithm generated an average annual return of 15.1%, which exceeded the average yearly return from the buy-and-hold strategy. Cohen conducted extensive research comparing technical methods with the buy-and-hold strategy for six U.S. ETFs tracking the S&P 500 (SPY), NASDAQ 100 (QQQ), Russell 2000 (IWM) and the financial (XLF), technology (XLK) and industrial (XLI) sectors, based on data from 1999 to 2018. In the study, he utilized signals generated by six indicators: RSI, stochastic oscillator, MACD, CCI, Money Flow, and Bollinger Bands. The results of Cohen's (2020) research indicated that the signals generated by the CCI and Bollinger Bands proved to be the most accurate, outperforming the buy-and-hold strategy. Cohen also demonstrated that the effectiveness of trading strategies depends on the level of market volatility and the specific combination of technical indicators employed. In some cases, technical strategies proved to be less accurate than the buy-and-hold strategy.

Numerous studies are related to Asian indices. Naved and Srivastava examined the accuracy of signals generated by oscillators, including the stochastic oscillator, RSI, and CCI, for the Indian S&P CNX Nifty 50 index from 2004 to 2014. The results of their research indicated that all three analyzed oscillators generate a similar level of signal accuracy. Slightly better results were observed for the CCI indicator, which outperformed the buy-and-hold strategy by 0.68%. Naved and Srivastava (2015) also demonstrated that the results achieved based on signals generated by individual indicators strongly depend on the period length used for their calculation. A study on the accuracy of RSI indicator signals for the Nifty 50 Index was conducted by Panigrahi, based on data from 2001 to 2020. In this case, the relative strength indicator was used to forecast the beginnings and ends of trends using the 50-50 and 40-60 levels. Panigrahi (2021) demonstrated that the first of the analyzed strategies yields better long-term results, while the second shows better short-term results. Although the rates of return from the analyzed strategies were positive in each year of the analysis, the results were statistically insignificant. Abbasi, Samavi, and Koosh (2020) compared the accuracy of various technical analysis indicators (Bollinger Bands, CCI, Moving Averages, Ichimoku, MACD, RSI, Stochastic Oscillator, and W%R) with the buy-and-hold strategy for ten Iranian stock indices from 2008 to 2018. The hypotheses for each index were tested, stating that there is no significant difference between the results of strategies based on technical analysis indicators and the buy-and-hold strategy over a one-year period. The research results enabled them to reject all hypotheses except the one for the automotive industry index, which showed varying accuracy depending on the specific industry being analyzed. A study was conducted by Christian, Hartini, Jayadi, and Asti to assess the accuracy of technical analysis indicators (moving average, stochastic oscillator, and MACD) for the Indonesian LQ45 Index using data from 2021. The study's results indicated that the stochastic oscillator indications exhibited the highest accuracy (Christian et al., 2022).

The most comprehensive studies on the accuracy of technical indicators were conducted using data from stock market indices across various geographic locations. Chong and Ng (2008), who in their previous studies showed that the RSI and MACD oscillator readings allowed for achieving better results than the buy-and-hold strategy for the British index, conducted another study together with Lie, in which this time they analyzed the accuracy of the above indicators for indices from various geographic locations (Milan Comit General (Italy), S&P/TSX Composite (Canada), DAX 30 (Germany), Dow Jones (USA), Nikkei 225 (Japan) based on data from 1976 to 2002. Chong, Ng, and Lie's (2014) research results indicated that strategies based on RSI and MACD oscillators generate different results depending on the market studied. In the case of the Italian and American indices, the studied trading rules outperformed the buy-and-hold strategy. In contrast, the classic strategy yielded higher returns for the Japanese index. Partially consistent conclusions were obtained by Cohen and Cabiri (2015), who examined the accuracy of signals generated by indicators such as RSI, MACD, Parabolic SAR, and stochastic oscillator in the years 2007-2012 for the following indices:

Dow Jones (the USA), FTSE 100 (the United Kingdom), Nikkei 225 (Japan), and TA100 (Israel). The results of their research indicated that the highest accuracy was characteristic of signals generated by the RSI indicator, which outperformed the buy-and-hold strategy for the following indices: American, British, and Japanese. The results for the American and British indices were consistent, whereas those for the Japanese index diverged from the results obtained by Chong, Ng, and Lie (2014). A similar study, which examined the accuracy of technical analysis indicators for the Dow Jones (the USA), Euro Stoxx 50 (Europe), and Nikkei 225 (Japan) indices from May 1, 2018, to May 1, 2020, was conducted by Teresiene and Aleksynaite. In this case, in addition to the RSI, MACD, and PSAR indicators, moving averages, ADX, VPT, MFI, and A/D were also used. Teresiene and Aleksynaite (2020) noticed that technical analysis indicators are characterized by a similar level of accuracy in different markets and that the signals generated by the indicators are consistent with each other in the case of similar price movements, e.g., after the declines caused by the beginning of the COVID-19 pandemic, the MACD, moving averages, PSAR, ADX, VPT, and A/D indicators denoted a buy signal. The RSI indications turned out to be neutral. Paik, Choi, and Vaquero (2024) conducted research proposing a model based on W%R indicators and the stochastic oscillator, utilizing data from ETF funds that reflect the values of the American S&P 500 index and the Korean MSCI Korea index from 2010 to 2022. The results of their research indicated that the proposed model outperformed the classic buy-and-hold strategy, achieving approximately 80% accuracy and generating an average of 1.5 transactions per year.

Table 1 summarizes the results of previous research on the accuracy of technical indicators for investing in stock market indices.

Table 1.
Summary of the results of previous research on the accuracy of technical indicators for investing in stock market indices

Author and year of publication	Index / ETF (country)	Indicators used	Main conclusions
Detry, Grégoire (2001)	Stock exchange indices from 15 European Union countries	Moving averages	The simplest technical analysis tools such as moving averages allow for accurate forecasting of European stock indices.
Fifield, Power, Sinclair (2005)	Hex (Finland), CAC-40 (France), DAX (Germany), Athens SE (Greece), BUX (Hungary), ISEQ (Ireland), MIB Storico (Italy), BVL (Portugal), Madrid SE (Spain), ISE National (Turkey), FTSE All Share (UK)	Moving averages	Emerging markets are characterized by greater predictability of returns than developed markets.
Chong, Ng (2008)	London Stock Exchange FT30 (UK)	MACD, RSI	Strategies based on RSI and MACD indicators allow for higher rates of return in most cases than the "buy and hold" strategy.

Cont. table 1.

Górska (2011)	WIG 20, WIG Food, WIG Fuels and WIG Chemistry (Poland)	Moving Averages, MACD, Momentum, CCI	In the case of all analysed indices, the "buy and hold" strategy generated higher rates of return than strategies based on technical indicators.
Trembiński, Stawska (2020)	DAX (Germany)	Moving Averages, RSI, CCI, Stochastic Oscillator, Ichimoku, Parabolic SAR, MACD, Bollinger Bands	Strategies based on technical indicators outperformed the buy-and-hold strategy in most cases, and during periods of increased volatility they protected the portfolio against losses to a greater extent.
Pistole, Metghalchi (2010)	S&P500 (US)	Moving Averages, Parabolic SAR, RSI	Moving averages and technical indicators PSAR and RSI both in the short (5 years) and long (17 years) periods outperform the "buy and hold" strategy. The highest statistically significant results were obtained in the case of the PSAR strategy.
Paik, Choim, Vaquero (2024)	S&P 500 (US)	Stochastic Oscillator, Williams %R, Trading Volume	The algorithm built on the basis of three technical indicators allowed to generate an average annual rate of return on the S&P500 index in the analyzed period at the level of 15.1%.
Cohen (2020)	S&P 500, NASDAQ 100, Russell 2000, XLF, XLK, XLI (US)	RSI, Stochastic Oscillator, MACD, CCI, MFI, Bollinger Bands	The signals generated by the CCI indicator and Bollinger Bands proved to be the most accurate, outperforming the "buy and hold" strategy. The effects of trading strategies depend on the level of market volatility and the combination of technical indicators adopted. In some cases, technical strategies proved to be less accurate than the "buy and hold" strategy.
Naved, Srivastava (2015)	S&P CNX Nifty 50 (India)	Stochastic Oscillator, RSI, CCI	The CCI indicator generated the highest results among the indicators tested. The result achieved on the basis of signals generated by individual indicators is strongly dependent on the length of the period used for its calculation.
Ebrahim, Samavi, Koosha (2020)	10 indexes of the Tehran Stock Exchange (Iran)	Bollinger Bands, CCI, Moving Averages, Ichimoku, MACD, RSI, Stochastic Oscillator, Williams %R	The validity of technical analysis strategies varies depending on the industry being analyzed.
Panigrahi (2021)	NIFTY 50 (India)	RSI	The 50-50 strategy is characterized by greater accuracy in the long term and the 60-40 in the short term. The rates of return from both technical strategies in each year of the study period turned out to be positive.
Christian, Hartini, Jayadi, Asti (2022)	LQ45 (Indonesia)	Moving Averages, Stochastic Oscillator, MACD	The stochastic oscillator readings were characterized by the highest accuracy.

Cont. table 1.

Chong, Ng, Lie (2014)	Milan Comit General (Italy), S&P/TSX Composite (Canada), DAX 30 (Germany), Dow Jones (USA), Nikkei 225 (Japan)	MACD, RSI	Strategies based on RSI and MACD generate varied results depending on the market studied. In the case of the Italian and American indices, the trading rules studied outperformed the buy-and-hold strategy, while in the case of the Japanese index, the classic strategy allowed for generating higher rates of return.
Cohen, Cabiri (2015)	Dow Jones (USA), FTSE 100 (UK), Nikkei 225 (Japan), TA100 (Israel)	RSI, MACD, Para-bolic SAR, Stochastic Oscillator	The highest accuracy was achieved by signals generated by the RSI indicator, which exceeded the results of the "buy and hold" strategy for the American, British and Japanese indices in five out of six years examined.
Teresienė, Aleksynaite (2020)	Dow Jones (USA), Euro Stoxx 50 (Europe), Nikkei 225 (Japan)	MACD, Moving Averages, RSI, Para-bolic SAR, ADX, VPT, MFI and A/D	Technical analysis indicators are characterized by a similar level of accuracy in different markets. In the case of similar price movements, identical signals appear in different markets.
Paik, Choi, Vaquero (2024)	S&P 500 (USA), MSCI Korea (South Korea)	William %R, stochastic oscillator	The proposed trading model was characterized by an accuracy level of 80% and exceeded the results of the "buy and hold" strategy.

Source: own study.

Based on the literature review, it is worth noting that the accuracy of signals generated by the RSI indicator was analyzed most often, in as many as 10 cases. Other frequently used indicators include MACD (9), moving averages (8), stochastic oscillator (7), CCI (5), and Parabolic SAR (4). The accuracy of technical analysis indicators was most often examined for the following indices: the S&P 500 (four times), the Nikkei 225, and the Dow Jones (three times each). Indices from a total of 27 countries and regions were examined; in 11 cases, they were American indices; in 10 cases, Iranian (the results of research on Iranian indices were presented in a separate article (Abbasi, 2020)); and in four cases, the indices of Germany, the United Kingdom, and Poland. In turn, considering the continents from which the individual indices originated, most often, in 36 cases, they were European indices (54.55% of all those examined), in 18 cases (27.27%) Asian, and in 12 cases (18.18%) North American. Based on the above analysis, it is worth noting that, in the literature, there is a limited number of studies comparing the accuracy of technical analysis indicators across markets from different regions of the world, with a notable focus on individual continents. In the case of cross-sectional studies, they primarily refer to indices from, at most, several countries, which represents an interesting research gap. It is also worth noting that studies on the accuracy of indicators for investments in indices are typically characterized by short research periods of several years or a few dozen years, omitting many years of the indices' existence, which is also an example of a research gap.

4. Research Methodology

The research strategy employed in this article is quantitative in nature. This research involves testing hypotheses (Czakon, 2016), and the data analysis aims to reveal or confirm the relationships between variable spresent in the studied investment strategies (Sułkowski et al., 2001).

Quantitative research was conducted from September 2024 to December 2024 using an MS Excel spreadsheet as a research tool. The study aimed to assess the effectiveness of using existing investment strategies, such as buy-and-hold and classic indicators, compared to newly defined avant-garde indicators, and to investigate the relationships between the use of all studied strategies and the return obtained from investing in a given stock index.

The study was designed as a data table using MS Excel, which was supplemented with values obtained from a website (Stooq.pl, 2025, March 15) containing historical data on global stock market indices. The database contained historical quotations of 63 global stock market indices from all continents, spanning from the beginning of each index to December 31, 2023, as this date marked the lastday of the completed full calendary earat the time of the study.

The computational stage of the research process was conducted using an MS Excel spreadsheet and was divided in to six parts.

- The first part of the study involved arranging the data for each studied indices in a separate table, clearly distinguishing the quotation date, opening price, high estsession price, lowe stsession price, and closing price.
- In the second part of the study, for each of the studiem indices, the values of verified classic indicators, such as RSI, CCI, W%R, DM, and ST, were calculated for each trading day. Based on this, potential days of purchase and sale of the security were determined for the selected indices.
- In the third part, days in which a signal with the same purpose was repeated were eliminated, allowing for subsequent signals in the buy-sell, buy-sell, etc. arrangement. If the last remaining signal was a buy, the sale price from the day of the previous quotations in the examined period was used. Then, all ordered signals were summed up for the adopted research period to obtain the final investment result for each classic indicator examined separately.
- In the fourth part of the study, the system of operation for new avant-garde indicators was defined, wchich consisted of using signals generated by all the classical indicator sstudied but in the opposite direction. The moment of purchase in this casemeant sale, and the sell signal defined purchase. In this way, five new indicators were obtained, which were named RSI_A, CCI_A, W%R_A, DM_A, and ST_A. The investment results achieved using the newly defined indicators were summarized.

- In the fifth part of the study, investment results were calculated using the standard buy-and-hold strategy, where it was assumed that the first day of quotation of each of the examined indices is the buy date, and December 31, 2023, i.e., the last day of the research period, is the sell date.
- In the last, sixth part of the study, the returns on investment were compared Rusing individual strategies, i.e., classic indicators, new avant-garde indicators, and the buy-and-hold strategy. It should be emphasized that the comparison of values consisted in recognizing the highest of them in all the strategies examined where, if the highest return on investment value was recognized in the group of classic indicators, the classic indicators were marked as the most economically advantageous method to use, if the highest return value occurred in the group of avant-garde indicators, they were marked as the most effective. If the value of the buy-and-hold strategy turned out to be the best, it was named the best strategy. The average values of the return on investment for the group of five classic indicators and five avant-garde indicators were also verified and compared with the buy-and-hold strategy. As before, the most economically advantageous method was determined to have the highest return on investment.

The analysis of the firstst age of the study's results, conducted using data from global stock market indices and an MS Excel spreadsheet, was subjected to statistical testing using the GRETL program.

- First, a summary specified which specific global stock market indices were examined.
- Next, tests were conducted to confirm or refute the hypotheses adopted in this article.
- Finally, synthetic results were presented to illustrate the effectiveness of the individual investment methods. For statistical verification, the probability of the first type of error was assumed to be 0.05 (alpha = 0.05).

To summarize, the study was quantitative in nature and conducted using historical data from 63 globalstock market indices. The analysis compared the effectiveness of classical technical indicators, newly defined avant-garde indicators, and the buy-and-hold strategy. Data processing was carried out in MS Excel, and statistical verification was performer using the GRETL program with a significance level of $\alpha = 0.05$. The results enabled an assessment of the effectiveness of the individual investment strategies.

5. Verification of Phenomena Influencing Strategies for Economically Advantageous Investment Results in Global Stock Market Indices

The study included 63 stock market indices, encompassing 32 indices from the European continent, 15 indices from the Asian continent, two indices from Australia, nine indices from North America, three indices from South America, one index from the African continent,

and one index covering the whole world. Knowing the characteristics of the information studied regarding global stock market indices and the conduct of the individual research parts, it was reasonable to analyze the results correctly. The first part verified the occurrence of selected phenomena that condition avant-garde indicators as the most economically advantageous when investing in global stock market indices included in the research hypotheses. The first test of the hypotheses was conducted using the proportion test, which involved comparing the number of more advantageous investment results obtained with avant-garde indicators with those obtained with classic indicators and the buy-and-hold strategy across 63 global stock market indices.

Based on the preliminary analysis of the results obtained using MS Excel software, it was expected that the results would be more economically advantageous for using avant-garde indicators. Therefore, a one-sided critical region was adopted for the analysis. The analysis results, employing the proportion test to assess the occurrence of a given phenomenon in the examined stock exchange indices, are presented in Table 2.

Table 2.
Proportion test analysis of the assessment of the occurrence of a given phenomenon in the examined stock exchange indices.

Assessment of the occurrence of a given phenomenon	**N**	**WSR**	**WSP**	**Z**	**P**
The use of avant-garde indicators presents higher return values than the use of classic indicators.	63	0,857143	0,142857	16,2019	2,446e-59*
The use of vanguard indicators shows higher return values than the use of a buy and hold strategy	63	0,68254	0,31746	6,22515	2,405e-10*

N - number of observations, WSR - structure index in the sample of positive answers, WSP - structure index in the sample of negative answers, z - value of the proportion test, p - significance level.

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The analysis of proportions for the first phenomenon, using avant-garde indicators as a solution presenting higher return values than classic indicators, showed that the hypothesis of equality of proportions should be rejected (z = 16.2019, p = 2.446e-59*). The hypothesis stating that there are more results regarding the use of avant-garde indicators as a solution that presents higher return values should be accepted.

The analysis of proportions for the secondo phenomenon, using avant-garde indicators as a solution that presents higher return values than the buy-and-hold strategy, showed that the hypothesis of proportione quality should be rejected (z = 6.22515, p = 2.405e-10). The hypothesis stating that there are more results regarding the use of avant-garde indicators as a solution that presents higher return values should be accepted.

In summary, both analyses regarding the use of avant-garde indicators showed that they provide higher return values than classical indicators and the buy-and-hold strategy. **Significantly more** results demonstrating these higher return values were obtained by

employing avant-garde indicators. This fact allowsus to akcept Hypothesis H1: **"The use of an investment strategy using the developer avant-garde indicators is more economically advantageous than the use of existing classic indicators for the main world stock exchange indices"**, and it also confirms Hypothesis H2: **"The use of an investment strategy using the developed avant-garde indicators is more economically advantageous than the use of the buy-and-hold strategy for the leading world stock exchange indices".**

The subsequent analysis aimed to verify Hypothesis H3, chich states that the use of avant-garde indicators shows the highest accuracy regardless of geographic location.

To verify, the stock market indices under study were divided in to six subgroups with different geographic distributions, such that they represented allcontinents with the lar gest number of studiem indices separately, and the remaining continents were combined into a separate subgroup. In this way, three continents were identified, representing the largest number of indices under study: Europe, Asia, SouthAmerica, and NorthAmerica. The remaining subgroups represented the following: all other continents excluding Europe, all other continents excluding Asia, and all other continents excluding the Americas. It should be emphasized that the number of indices dictated the above division on each of the individual continents, where if the number of indices under study presented a value below 10, the given continent was not distinguished as a separate subgroup due to the small amount of data (below 15% of the en tire population). The exception was the continent of North America and South America, where, to obtain the minimum amount of data, the results of both continents were summarized due to similarities resulting from national conditions.

To verify Hypothesis H3, a *t*-test was conducted first. This allowed us to determine whether there are significant differences in the application of the studied investment methods between the designated subgroups representing the continents with the largest number of studied indices. It should be emphasized that, despite dividing the studied stock exchange indices in to smaller subgroups and thus reducing the number of samples within a given subgroup. The literature (Meek et al., 2007) allows for the use of the *t*-test for small sample sizes. The results of the *t*-test analysis, assessing differences in the number of results that are more economically advantageous for the applied investment methods in the studiem stock exchange indices, categorized into Europe and the remaining continents, are presented in Table 3.

Table 3.
T-test analysis of the assessment of differences in the number of economically more advantageous results for the investment methods used in the examined stock exchange indices, divided into Europe and other continents.

	Europe			**Other continents without Europe**				
Evaluation of differences in the number of results more favorable for the investment methods used	**N**	**M**	**Q**	**N**	**M**	**Q**	t	p
Investment strategies	32	10,67	10,97	31	10,33	8,02	0,140058	0,445

N - number of observations, M - sample mean, Q - standard deviation, t - test value, p - significance level

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The *t*-test analysis to determine whether there are significant differences in the results of the European indices and those of the other continents, excluding Europe, regarding the number of results more economicallyadvantageous for the applied investment methods, yielded a *p*-value of 0.445 (t = 0.140058). Therefore, the hypothesis should be accepted that the results of the European indices and the other continents **do not differ significantly**. The results of the *t*-test analysis assessing differences in the number of results that are more economicallyadvantageous for the applied investment methods in the examined stock exchange indices, divided into North America, South America, and all other continents, excluding the Americas, are presented in Table 4.

Table 4.
T-test analysis of the assessment of differences in the number of economically more advantageous results for the investment methods used in the examined stock exchange indices, divided into North and South America and other continents, excluding the Americas

	North and South America			Other continents excluding the Americas				
Other continents excluding the Americas	N	M	Q	N	M	Q	T	p
Investment strategies	12	4	3	51	17	17,78	-2,50974	0,007376*

N - number of observations, M - sample mean, Q - standard deviation, t - test value, p - significance level.

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The *t*-test analysis to determine whether there are significant differences in the results of the American indices and those of the other continents, excluding the Americas, regarding the number of more economically advantageous results for the applied investment methods showed a considerable difference (t = -2.50974, p = 0.007376*). Therefore, the hypothesis should be accepted that the results of the American indices and the other continents, excluding the Americas, **differ significantly**. The results of the *t*-test analysis, assessing differences in the number of more economically advantageous outcomes for the applied investment strategies in the examined stock exchange indices, are presented in Table 5, divided into Asia and the other continents excluding Asia.

Table 5.
T-test analysis of the assessment of differences in the number of economically more advantageous results for the applied investment strategies in the examined stock exchange indices, divided into Asia and other continents, excluding Asia

	Asia			Other continents excluding Asia				
Evaluation of differences in the effectiveness of the investment strategies used	N	M	Q	N	M	Q	T	p
Investment strategies	15	5	7	48	16	12	-3,36402	0,0006661*

N - number of observations, M - sample mean, Q - standard deviation, t - test value, p - significance level.

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The *t*-test analysis to determine whether there are significant differences in the results of the Asian indices and those of the other continents excluding Asia regarding the number of results that are more economically advantageous for the applied investment strategies showed a considerable difference (t = -3.36402, p = 0.0006661*). Therefore, the hypothesis should be accepted that the results of the Asian indices **differ significantly** from those of the other continents.

In summary, the *t*-test revealed no significant differences in the number of more economically advantageous results obtained for the applied investment strategies across European indices and all other continents. In the groups of American indices and different continents, as well as Asian indices and other continents, the *t*-test revealed significant differences in the number of economically advantageous results obtained for the applied investment strategies. Due to the diversified results in the area of the designated subgroups, it was justified to conduct the second part of the analysis, which consisted of assessing the significance of the application of individual investment strategies separately for each of these subgroups to determine whether the application of avant-garde indicators shows the highest accuracy regardless of geographic location.

The analysis was conducted based on the proportion test. The test determined whether the number of results more economically advantageous for applying individual investment strategies constitutes a significant majority of all the results obtained for indices in designated geographic subgroups. Because in the area of division of indices into geographic subgroups, we cannot determine whether the strategy shows a right- or left-sided direction of changes, a two-sided critical region was applied.

Since, based on the *t*-test results, the European indices were expected to yield the same results for individual investment strategies as the entire studied group (all other continents, excluding Europe), the first analysis to be carried out was amateriality analysis of applying individual investment strategies to the European continent (see Table 6).

Table 6.
Proportion test analysis of the assessment of the investment strategies used for the European continent

Assessment of the application of individual investment strategies	Assessment of the application of individual investment strategies				
	N	WSR	WSP	Z	p
B&H Strategy	32	0,21875	0,5	-3,18198	0,001463*
Strategy Classic Indicators	32	0,0625	0,5	-4,94975	7,431e-07*
StrategyVanguardIndicators	32	0,71875	0,5	2,47487	0,01333*

N - number of observations, WSR - structure index in the sample of positive answers, WSP - structure index in the sample of negative answers, z - value of the proportion test, p - significance level

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The analysis of proportions for the assessment of the applied investment strategies for the European continent indicated that for one strategy (Avant-Garde Indicator Strategy), which showed (z = 2.47487, p = 0.006664) where the *z*-value revealed a right-sided critical

region, it is reasonable to reject the hypothesis that the proportion of the sample of economically advantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the proportion of economically advantageous results for the Avant-Garde Indicator Strategy is significantly greater than 50% of all results should be accepted.

For the two remaining strategies (Buy-and-Hold Strategy, Classic Indicators Strategy), which showed (z = -3.18198, p = 0.0007314) and (z = -4.94975, p = 3.715e-07) respectively, where the *z*-values revealed the left-sided critical region, it is reasonable to reject the hypothesis that the sample proportion of more economically advantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the sample proportion of more economicallyadvantageous results for the Buy-and-Hold Strategy and the Classic Indicator Strategy is significantly smaller than 50% of all results should be accepted.

In the American and all other continental indices, as well as inthe Asian and all other continental indices, the *t*-test revealed significant differences in the number of results obtained, which were more economicallyadvantageous for the applied investment strategies. Therefore, the significance of applying individual investment strategies was analyzed separately for each group. The results of the analysis, using the proportion test to assess the applied investment strategies for the American and all other continents, are presented in Table 7.

Table 7.
Proportion test analysis of the evaluation of the investment strategies used for the American and other continents

Assessment of the application of individual investment strategies	American continents					Other continents excluding the Americas				
	N	WSR	WSP	z	P	N	WSR	WSP	z	p
B&H Strategy	12	0,583	0,5	0,577	0,5637	51	0,216	0,5	-4,06	0,001279*
Classic Indicators Strategy	12	0,083	0,5	-2,887	0,003892*	51	0,058	0,5	-6,30	2,952e-10*
Strategy Vanguard Indicators	12	0,333	0,5	-1,155	0,2482	51	0,73	0,5	3,22	0,0006395*

N - number of observations, WSR - structure index in the sample of positive answers, WSP - structure index in the sample of negative answers, z - value of the proportion test, p - significance level.

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The analysis of proportions for the evaluation of the applied investment strategies for the American continents showed that for one strategy (Classic Indicator Strategy), which shows (z = -2.887, p = 0.003892) where the *z*-value revealed the left-sided critical region, it is reasonable to reject the hypothesis that the proportion of the sample of the number of more economicallyadvantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the proportion of the sample of more economically advantageous results for the Classic Indicator Strategy is significantly smaller than 50% of all results should be accepted.

For the remaining two strategies in the group of American continents, Buy-and-Hold Strategy and Avant-Garde Indicator Strategy, the results showed (z = 0.577, p = 0.5637) and (z = -1.155, p = 0.2482), respectively, it is reasonable to accept the hypothesis that the sample proportion of the number of more economically advantageous results for individual financial strategies constitutes 50% of the results.

In the group of the remaining continents, two investment strategies (Buy-and-Hold Strategy and Classic Indicator Strategy), where the *z*-values revealed a left-sided critical region, showed (z = -4.06, p = 0.001279) and (z = -6.30, p = 2.952e-10), respectively, which justifies the rejection of the hypothesis that the sample proportion of more economically advantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the sample proportion of more economically advantageous results for the Buy-and-Hold Strategy and the Classic Indicator Strategy is significantly smaller than 50% of all results should be accepted.

The third investment strategy in the group of other continents for the Avant-Garde Indicator Strategy showed (z = 3.22, p = 0.006395), where the *z*-value revealed a right-sided critical region, it is reasonable to reject the hypothesis that the proportion of the sample of the number of more economicallyadvantageous results for individual financial strategies constitutes 50% of the results. The hypothesis, which states that the proportion of the sample of more economically advantageous results for the Avant-Garde Indicator Strategy is significantly greater than 50% of all results, should be accepted. The results of the proportion test analysis, assessing the investment strategies employed for the Asian continent and all other continents excluding Asia, are presented in Table 8.

Table 8.
Proportion test analysis of the evaluation of the investment strategies used for the Asian continent and other continents except Asia

Assessment of the application of individual investment strategies	Asian continent					Other continents excluding Asia				
	N	WSR	WSP	Z	P	N	WSR	WSP	z	p
B&H Strategy	15	0,133	0,5	-2,840	0,004509*	48	0,333	0,5	-2,309	0,02092*
Strategy Classic Indicators	15	0	0,5	-	-	48	0,083	0,5	-5,774	7,764e-09*
Strategy Vanguard Indicators	15	0,866	0,5	2,840	0,002254*	48	0,583	0,5	1,155	0,2482

N - number of observations, WSR - structure index in the sample of positive answers, WSP - structure index in the sample of negative answers, z - value of the proportion test, p - significance level.

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The analysis of proportions for the assessment of the applied investment strategies for the Asian continent indicated that for the Strategy of Avant-Garde Indicators, which showed (z = 2.840, p = 0.002254) where the *z*-value revealed a right-sided critical region, it is reasonable to reject the hypothesis that the proportion of the sample of the number of more economically advantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the proportion of the sample of more economically advantageous results for the Strategy of Avant-Garde Indicators is significantly greater than 50% of all results should be accepted.

For the next strategy under study, the Buy-and-Hold Strategy, which yielded a *z*-value of -2.840 (p = 0.004509), where the *z*-value indicated a left-sided critical region, it is reasonable to reject the hypothesis that the sample proportion of more economically advantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the sample proportion of more economicallyadvantageous results for the Buy-and-Hold Strategy is significantly less than 50% of all results should be accepted.

For the last strategy examined (Classic Indicator Strategy), the structure indicator in the sample is 0, which means that this feature was not present in the examined sample.

In the second studied group, all other continents without Asia, the analysis of proportions for the assessment of the applied investment strategies for the Asian continent indicated that for two strategies (Buy-and-Hold Strategy and Classical Indicator Strategy), which showed (z = -2.309, p = 0.02092) and (z = -5.774, p = 7.764e-09), respectively, the *z*-values revealed the left-sided critical region, which means that it is justified to reject the hypothesis that the proportion of the sample of the number of more economically advantageous results for individual financial strategies constitutes 50% of the results. The hypothesis that the proportion of sample results more economically advantageous for the Buy-and-Hold Indicators Strategy and the Classical Indicators Strategy is significantly smaller than 50% of all results should be accepted.

For the Avant-Garde Indicators investment strategy in the group of all other continents excluding Asia, the analysis showed (z=1.155, 0.2482), which indicated a right-sided critical region and there was no basis to reject the hypothesis that the sample proportion of more economically advantageous results for individual financial strategies constitutes 50% of the results.

After conducting both parts of the analysis to confirm the third hypothesis presented in this article, which investigates whether the use of avant-garde indicators yields the highest accuracy regardless of geographic location, a synthetic summary of the results is presented in Table 9.

Table 9.
Summary of analyses using the proportion test to assess the investment strategies used for individual groups of continents

Summary of the application of individual investment strategies	European continent	American continents	Other continents excluding the Americas	Asian Continent	Other continents excluding Asia
B&H Strategy	WKE < 50%	WKE = 50%	WKE < 50%	WKE < 50%	WKE < 50%
Strategy Classic Indicators	WKE < 50%	WKE < 50%	WKE < 50%	No feature in the sample	WKE < 50%
StrategyVanguardIndicators	WKE > 50%	WKE = 50%	WKE > 50%	WKE > 50%	WKE = 50%

WKE - economicallymoreadvantageousresults.

Source: Ownstudybased on a study of rates of return on globalstock exchange indicesusing the GRETL program.

The analysis showed that applying the Buy-and-Hold and Classic Indicator investment strategies yields significantly fewer economically advantageous results for practically all the groups of continents examined. The exceptions are the American continents, where the Buy-and-Hold Strategy yielded similar results to the Avant-Garde Indicator Strategy, with the number of economically advantageous results falling within 50% of the results. For the Classic Indicator Strategy for the Asian continent, there is no feature corresponding to the sample.

Applying the Avant-Garde Indicators investment strategy enabled us to achieve a significantly higher number of more economically advantageous results for the three examined groups of continents: the European continent, all other continents excluding the Americas, and the Asian continent. For the remaining groups of continents – the American continents and all other continents excluding Asia – the application of the Avant-Garde Indicator strategy yielded a number of economically advantageous results, accounting for approximately 50% of the total results. However, it should be remembered that all other continents, excluding the Asian group, include the indices of the American continents, which may affect the outcome of this entire group by lowering the alpha value due to the higher number of economically advantageous results in the Avant-Garde Indicators investment strategy group. Therefore, another proportion test was conducted to confirm whether the indices for the American continent improve the results of the subgroup of other continents, excluding Asia, and whether they demonstrate the same properties as all subgroups except those from the American continents (see Table 10).

Table 10.
Proportion test analysis of the assessment of the investment strategies used for the remaining continents, excluding Asia and the Americas

Assessment of the application of individual investment strategies	Other continents excluding Asia and the Americas				
	N	WSR	WSP	Z	p
B&H Strategy	48	0,25	0,5	-3	0,0027*
Strategy Classic Indicators	48	0,0834	0,5	-4,9992	5,757e-07*
StrategyVanguardIndicators	48	0,667	0,5	2,004	0,04507*

N - number of observations, WSR - structure index in the sample of positive answers, WSP - structure index in the sample of negative answers, z - value of the proportion test, p - significance level

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

As expected, additional proportion analysis for assessing the investment strategies used for the remaining continents, excluding Asia and the Americas, revealed the same trend as all the examined groups of continents, except for the American continents.

In summary, the avant-garde indicator strategy generated a significantly higher number of economically favorable outcomes compared to the other strategies applied, with the exception of the American continents, where both the avant-garde indicator strategy and the buy-and-hold strategy yielded similarly beneficial results. This outcome partially confirms Hypothesis H3, which assumes the geographical robustness of avant-garde indicators, while also extending it by suggesting that outside the Americas, the effectiveness of avant-garde indicators is clearly superior.

Although Hypothesis H3 posits the universal applicability of this approach, the results revealed notable regional differences, particularly across the Americas. A possible explanation for these discrepancies may lie in macroeconomic factors (e.g., interest rate levels, inflation), geopolitical conditions (e.g., political stability, market regulations), and structural characteristics (e.g., dominance of specific sectors in regional indices). For instance, American indices are known for their high informational efficiency and liquidity, which may limit the advantage of technical strategies. Future research should consider incorporating these variables as additional dimensions of analysis to better understand the contextual limitations and strengths of avant-garde indicators in global markets.

6. Summary and Discussion

The conducted research has shown that the application of an investment strategy using the developed Avant-Garde Indicators is more economically advantageous than the application of the existing Classic Indicators and the Buy-and-Hold Strategy for the leading world stock market indices, with the proviso that for the American continents the Avant-Garde Indicator Strategy brings similar results to the Buy-and-Hold Strategy. However, it is worth noting that five new indicators were identified in the Avant-Garde Indicator Strategy, and their highest results were analyzed for each of the examined indices. At this point, the question arises of whether significantly more economically advantageous results would be obtained when selecting any of the five newly developed indicators that are part of the Avant-Gard Indicator Strategy than when using the other examined strategies.

In anattempt to answer this question, another analysis was conducted, using the proportion test, which consisted in comparing the number of more favorable investment results using avant-garde indicators to the number of more favorable investment results using classic indicators and the buy-and-hold strategy, with the proviso that the average values of return on investment in the group of five classic indicators and the group of five avant-garde indicators

would be adopted for the study, and not the highest values in the group as hadbeen the case in earlier analyses (seeTable 11).

Table 11.
Proportion test analysis of the assessment of the occurrence of a given phenomenon in the examined stock exchange indices after changing the method of selecting the most favorable value in the group of Avant-Garde and Classic Indicators

Assessment of the occurrence of a given phenomenon	N	WSR	WSP	Z	p
The average return value of the Avant-Garde Indicators group is higher than the average return value of the Classic Indicators group	63	0,904762	0,095238	21,8891	1,65e-106
The average return of the Vanguard Indicators group is higher than the return of the "buy and hold" strategy	63	0,460317	0,539683	-1,26388	0,1031

N - number of observations, WSR - structure index in the sample of positive answers, WSP - structure index in the sample of negative answers, z - value of the proportion test, p - significance level.

Source: Own study based on a study of rates of return on global stock exchange indices using the GRETL program.

The analysis of proportions for the first phenomenon – the average return value of the Avant-Garde Indicators being higher than that of the Classic Indicators – showed that the hypothesis of equality of proportions should be rejected (z = 21.8891, p = 1.65e-106). The hypothesis that the average return value of the Avant-Garde Indicators group is higher than that of the Classic Indicators group should be accepted.

The analysis of proportions for the second phenomenon – the average return value of the Avant-Garde Indicator Group being higher than the average return value of the buy-and-hold strategy – showed that there is no basis for rejecting the hypothesis of equality of proportions (z = -1.26388, p = 0.1031*).

To summarize, the analysis comparing the average return value from the group of Avant-Garde Indicators with that from the group of Classic Indicators revealed significantly more results with a higher average return value for the Avant-Garde indicators. On the other hand, for the analysis concerning the average return value from the group of Avant-Garde Indicators, which is higher than that of the Buy-and-Hold Strategy, significantly more results with a higher average return value were obtained. Therefore, the conclusion is that by selecting any indicator from the examined group of Avant-Garde Indicators, we will, on average, receive a higher return on investment than by choosing an indicator from the group of Classic Indicators. In contrast, the obtained return value will not exceed that of the Buy-and-Hold Strategy.

This fact suggests that to achieve the highest possible return on investment using the examined investment strategies, it is necessary to analyze historical data for a given index across all five indicators from the group of newly developed Avant-Garde Indicators and select the most profitable.

The results of the conducted research also encourage further exploration and investigation of potential relationships based on the newly identified Avant-Garde Indicators, which may ultimately lead to the development of a single, universal indicator that consistently demonstrates the highest economic efficiency of the investment under given conditions.

It should also be noted that the results of this research constitute a breakthrough in terms of the universal nature of applying investment strategies to various geographic locations, as a considerable number of authors compare the accuracy of technical analysis indicators for individual continents or, in the case of cross-sectional studies, narrow it down to only a few countries.

In addition, previous studies are typically characterized by short research periods of several years or less, often omitting many years of the indices' existence. In contrast, the research conducted in this article treats the data of global stock exchange indices holistically. It analyzed data available from the beginning of each of them, which allowed us to neutralize the effects of occasional fluctuations in quotations related to the specific economic situation of a given period. Thanks to this, it was possible to increase the transparency of the results, eliminating the risk of falsifying the actual research result.

It is also worth noting that the research on the accuracy of indicators for investing in indices presented by other researchers is mainly based on existing technical analysis indicators, contrary to the research presented in this article, which focuses on searching for new methods that allow for the development of even more effective ways of investing in stock market indices than those known so far. Thus, taking into account the fact that many researchers whose research results are cited in this article present the superiority of technical analysis methods over the buy and hold strategy, this research presents for the first time the superiority of the newly developed technical analysis method, which is the Avant-Garde Indicators over the Classic Indicators for all geographic regions.

It should be emphasized, however, that the conducted study has certain limitations resulting from the omission of trans action costs, price slippage, and liquidity constraints, all of which can significantly affect the actual performance of investment strategies based on technical signals. A particularly important aspectis the frequent positions witching generated by some indicators, which may lead to increased operational costs and, consequently, reduce the effectiveness of the strategy under real market conditions. Therefore, future research should consider these factors by implementing trans action simulations or analyzing data from markets with varying levels of liquidity, which would allow for a more comprehensive understanding of the practical potential and limitations of the strategies under examination.

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Appendix

List of global stock market indices examined

LP	Ticker	Index	Country	Continent	Beginning of the research period
1	^AOR	ALL ORDINARIES	Australia	Australia	01.01.1875
2	^HSI	HANG SENG	Hong Kong	Asia	24.11.1969
3	^JCI	JCI	Indonesia	Asia	04.04.1983
4	^KLCI	KLCI	Malaysia	Asia	03.01.1977
5	^KOSPI	KOSPI	South Korea	Asia	04.01.1980
6	^NKX	NIKKEI225	Japan	Asia	01.03.1914
7	^NZ50	NZX50	New Zealand	Australia	03.01.2001
8	^PSEI	PSEI	Philippines	Asia	02.01.1986
9	^SET	SET	Thailand	Asia	30.04.1975
10	^SHBS	SSE B-SHARE	China	Asia	04.01.2000
11	^SHC	SSE COMP	China	Asia	19.12.1990
12	^SNX	SENSEX	India	Asia	03.04.1979
13	^STI	STRAITS TIMES	Singapore	Asia	28.12.1987
14	^TWSE	TAIEX	Taiwan	Asia	05.01.1995
15	A5.C	ATX INDEX	Austria	Asia	11.11.1992
16	^AEX	AEX	Netherlands	Europe	03.01.1983
17	^ATH	ATHEX COMP	Greece	Europe	02.01.1987
18	^BEL20	BEL20	Belgium	Europe	02.01.1991
19	^BET	BET	Romania	Europe	31.10.2000
20	^BUX	BUX	Hungary	Europe	02.01.1991
21	^CAC	CAC40	France	Europe	08.01.1965
22	^DAX	DAX	Germany	Europe	28.09.1959
23	^FMIB	FTSE MIB	Italy	Europe	02.01.1998
24	^FTM	FTSE250	Great Britain	Europe	31.12.1985
25	^HEX	HEX	Finland	Europe	02.01.1995
26	^IBEX	IBEX35	Spain	Europe	05.01.1987
27	^ICEX	ICEX	Iceland	Europe	31.12.1992
28	^MDAX	MDAX	Germany	Europe	29.02.1996
29	^MOEX	MOEX	Russia	Europe	22.09.1997
30	^OMXC25	OMX COPENHAGEN 25	Denmark	Europe	19.12.2016
31	^OMXR	OMX RIGA	Latvia	Europe	03.01.2000
32	DJI	Dow_Jones_Industrial_US	USA	Europe	27.05.1896
33	DJC	Dow_Jones_Composite_US	USA	Europe	23.12.1980
34	BVP	Bovespa_Index_Brazil	Brazil	Europe	12.07.1989
35	WIG20	WIG20_PL	Poland	Europe	16.04.1991
36	WIG	WIG_PL	Poland	Europe	16.04.1991
37	UX	UX_Index_Ukraine	Ukraine	Europe	03.11.1997
38	SOFIX	SOFIX_Index_Bulgaria	Bulgaria	Europe	26.11.2001
39	SAX	SAX_Index_Slovakia	Slovakia	Asia	03.07.1995
40	OSEAX	OSE_Index_Norway	Norway	Europe	03.01.1983
41	SMI	SWISS_Market_Index	Switzerland	Europe	01.07.1988
42	RTS	RTS_Index_USD_Russia	Russia	Europe	01.09.1995
43	PSI20	PSI20_Index_Portugal	Portugal	NorthAmerica	31.12.1992
44	SDXP	sDAX_Germany	Germany	NorthAmerica	15.03.1999
45	PX	PX_Index_Czech	Czech Republic	SouthAmerica	07.09.1993
46	UKX	UK100CFD_United_Kingdom	Great Britain	Europe	13.11.1935
47	IPSA	IPSA_Index_Chile	Chile	Europe	02.01.1987
48	OMXT	OMX_Tallinn_Index_Eston	Estonia	Europe	03.01.2000
49	OMXV	OMX_Viilnius_Index	Lithuania	Europe	03.01.2000

50	MRV	Merval_Index_Argentina	Argentina	Europe	04.04.1988
51	XU	XU100_Turkey	Turkey	Europe	02.01.1990
52	NDX	Nasdaq_100_U.S.	USA	Europe	01.10.1985
53	DJT	Dow_Jones_Transportation_U.S.	USA	Europe	26.10.1896
54	CRY	CRB_Commodity_Index	Freight	Europe	03.01.1994
55	TSX	TSX_Composite_Canda	Canada	Europe	31.01.1956
56	TASI	tasi_Tadawul_All_Share_Index	Arabia Saudi	Europe	12.07.2001
57	DJU	Down_Jones_Utilities_U.S.	USA	Europe	02.01.1929
58	SPX	S&P 500 U.S.	USA	Europe	01.05.1789
59	IPC	Mexican_Boelsa_Index_Mexico	Mexico	SouthAmerica	08.11.1991
60	NDQ	Nasdaq_Composite_U.S.	USA	Europe	03.01.1938
61	TDXP	TexDAXGermany	Germany	Europe	16.09.1999
62	OMXS	OMXS_Stockholm_30_Index_Sweden	Sweden	Europe	30.09.1986
63	TOP40	JSE Top 40		SouthAmerica	03.07.1995