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Combining value and momentum in the German stock market

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ABSTRACT :

This thesis investigates the performance of value and momentum strategies in the German stock market, focusing on long-, short- and long-short portfolios. It aims to determine whether value and momentum strategies, individually or combined, deliver abnormal risk-adjusted returns compared to the market. Previous studies have extensively explored these strategies in various markets, primarily in the U.S. and wider European market, but this work seeks to extend the analysis to the German context, offering new insights into the efficacy of value and momentum strategies in this specific market environment.

The research methodology involves constructing portfolios based on value and momentum factors and assessing their performance against the German stock market. This study is distinctive because it examines the potential synergies between value and momentum strategies when they are integrated, addressing a gap in the literature regarding their combined effect in the German market.

The findings reveal that both value and momentum strategies, as well as their combination, can generate significant risk-adjusted returns, outperforming the market. The results further indicate that the combined strategies enhance the portfolios' overall performance, suggesting that the integration of value and momentum factors may offer a more effective investment approach in the German stock market than employing single-factor strategies alone.

KEYWORDS: value, momentum, factor investing

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TIIVISTELMÄ:

Tämä tutkielma selvittää arvo- ja momentumstrategioiden tehokkuutta Saksan osakemarkkinoilla. Tutkimuksen päätavoitteena on selvittää, kykenevätkö arvo- ja momentumstrategiat, erikseen tai yhdistettynä, saavuttamaan markkinakeskiarvon ylittäviä riskikorjattuja tuottoja. Vaikka aiempi tutkimus on laajalti käsitellyt näitä sijoitusstrategioita useissa markkinaympäristöissä, erityisesti Yhdysvalloissa ja Euroopan laajemmassa mittakaavassa, tämä tutkielma laajentaa olemassa olevaa tietopohjaa tuomalla esiin näiden strategioiden potentiaalin Saksan markkinoilla.

Tutkimusmetodologiana hyödynnetään arvo- ja momentumperusteisten salkkujen muodostamista, joka kattaa strategiat pitkille, lyhyille sekä yhdistelmä (pitkä/lyhyt) portfolioille. Erityistä huomiota kiinnitetään arvo- ja momentumstrategioiden yhdistämisen mahdollisiin synergiaetuihin, mikä edustaa merkittävää lisäystä alan kirjallisuuteen, erityisesti Saksan markkinoiden kontekstissa.

Havainnot vahvistavat, että sekä arvo- että momentumstrategiat, myös niiden strateginen yhdistäminen, voivat tuottaa huomattavia riskikorjattuja tuottoja, jotka ylittävät Saksan osakemarkkinoiden keskimääräisen tuoton. Lisäksi tulokset viittaavat siihen, että näiden strategioiden integrointi voi parantaa sijoitussalkkujen kokonaistuottavuutta, mikä osoittaa, että arvo- ja momentumstrategioiden yhdistelmä saattaa tarjota ylivoimaisen sijoitusstrategian Saksan osakemarkkinoilla verrattuna pelkästään yksittäisiin faktoreihin nojautuviin lähestymistapoihin.

AVAINSANAT: arvo, momentum, faktorisijoittaminen

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1 Introduction

Previous literature has provided substantial evidence that markets are not entirely efficient and that various factors drive returns in stock prices. Notable among these factors are market, size, value, profitability, investment, and momentum. By constructing portfolios based on these factors, investors can potentially achieve enhanced risk-adjusted returns. The influence of these factors varies across different market regions and periods, with certain factors performing better under specific conditions. Researchers such as Fama and French (1993, 2015, 2018) have developed factor models to capture these excess returns and to explain the primary drivers behind them.

One of the most significant stock market anomalies is the momentum anomaly. The momentum anomaly refers to the observed phenomenon in financial markets where stocks that have performed well in the past continue to outperform, and those that have performed poorly tend to continue underperforming. The anomaly allows for an investment strategy that follows market movements by taking long positions in high-returning “winners” stocks while short-selling those on a downward trend “losers”. The strategy relies on the expectation that the previous return trend will continue, partly due to behavioral biases in which investors collectively become overconfident in winners while losers fall out of favor. Complementing this, Jegadeesh and Titman’s (1993) research revealed that momentum strategies have historically produced abnormal returns over extended periods. Building on this foundation, more recent studies, such as Ehsani and Linnainmaa (2022), have confirmed the persistence of significant momentum returns in equities, further solidifying the relevance of momentum strategies.

The value anomaly refers to a phenomenon where stocks that are undervalued identified by fundamental metrics such as low price-to-book (P/B) ratios consistently outperform their overvalued counterparts. The value strategy seeks undervalued assets compared to their intrinsic value, as these assets are likely to revert to their fair value over time. The long-short value investing is based on purchasing undervalued “value” stocks and

short-selling overpriced “growth” stocks. The measure for the undervalued and overvalued stocks comes from the book-to-market ratio. Graham and Dodd's (1934) seminal work laid the foundation for value investing, highlighting that over long periods, value stocks have historically outperformed growth stocks. However, more recent findings, such as those by Fama and French (2020), suggest that this value anomaly may be diminishing, at least within U.S. equities. This evolution raises questions about the persistence of the value premium in modern markets and whether the principles of value investing still hold.

Researchers examining investment factors have shown a negative correlation between the value and momentum factors (e.g., Asness et al., 2013). This correlation suggests a strategic benefit in combining these two approaches, as each has demonstrated strong performance during distinct market cycle phases. Moreover, a combined strategy that leverages both value and momentum anomalies could potentially enhance returns by exploiting the different market cycles. This strategy can benefit from long-term performance while controlling volatility risk. By focusing on only two factors and employing integrated methods, transaction fees can potentially be minimized while enhancing risk-adjusted returns. There is a scarcity of studies on the combination of momentum and value premiums within the German stock universe, which presents an opportunity to contribute to current research. Additionally, compared to the extensive history of research in the financial industry, the integration strategy remains a relatively recent concept.

1.1 Purpose of the study

The purpose of the study is to investigate the value and momentum premiums in the German stock market by using existing studies as a foundation for the most effective methods of integrating these two approaches. The central focus is to determine whether a combined strategy, allocating 50% of a portfolio to value and 50% to a momentum strategy, can outperform standalone value or momentum strategies. The study also aims

to investigate whether the integrated method of value and momentum outperforms the mixing approach. It will seek optimal portfolio implementation methods to enhance the effectiveness of value or momentum strategies individually. The study will examine which strategy yields the highest risk-adjusted and raw returns.

Despite its strong returns, the momentum anomaly can be vulnerable to crash risk during rapid shifts in market sentiment. Value investing can be perceived as an effective factor for hedging against the volatility inherent in momentum strategies, due to its potential negative correlation with momentum. Beyond raw returns, the study gives weight to risk-adjusted metrics like CAPM, Fama-French factors, and Sharpe ratio. The CAPM alpha measures whether the portfolios succeeded in achieving returns higher than the benchmark index through its beta. In contrast, the Fama-French alpha assesses whether the excess returns over the benchmark index can be attributed to heightened exposure to specific risk factors. This will provide a thorough understanding of the strategy's viability.

The results are divided into two categories: single-factor and multifactor portfolio returns. These results are examined across the entire sample as well as within specific subsamples that are segmented according to market capitalization. This intends to determine whether the observed effects of the factors are predominantly attributable to large-cap stocks or small-cap stocks. Additionally, the aim is to examine the potential negative correlation between value and momentum strategies, as indicated by previous studies.

This research aims to determine whether investment strategies continue to yield returns in a concentrated market context, specifically within Europe's largest economy. The research intends to explore the combination of momentum and value strategies, building upon the foundation laid by scholars such as Asness et al. (2013), Fisher et al. (2016), Grobys and Huhta-Halkola (2019), Silvasti et al. (2021). The strategies have been exten-

sively studied across global markets and the U.S. However, there exists a scarcity of research specifically examining their effectiveness within the German markets. This thesis differs from previous studies by concentrating on the German market, and additionally, it restricts the study to two specific factors. Consequently, the findings of this study are expected to be comparable with existing research in the field.

1.2 Research question and hypothesis

This study examines momentum and value anomalies in the German stock market and explores the possibility of achieving superior risk-adjusted returns in terms of CAPM, 5- and 6-factor models. Importantly, it investigates whether mixing or integrating these strategies can improve both portfolio risk-adjusted returns and overall performance. The hypotheses are as follows:

H1: stocks with high past book-to-market ratios outperform the market index.

The results are projected to align with earlier studies where stocks with high past book-to-market ratios have generated excess returns over the market index. Recent studies with these outcomes include (see e.g. Fama and French, 1992; Rosenberg et al., 1985; Lakonishok, 1994; Chan et al., 2004; Hanauer and Windmuller, 2023). This hypothesis aims to confirm the persistence of the value anomaly within the German market, adding to the validation of value investing principles in different geographical contexts.

H2: Stocks with high past returns will generate abnormal returns compared to the market index.

The results are projected to align with earlier studies where stocks with high (low) past returns have generated excess returns over the market index. Previous research has demonstrated this concept (see e.g., Jegadeesh and Titman, 1993; Asness et al., 1997; Fama and French, 1998; Jegadeesh and Titman, 2001; Grobys and Huhta-Halkola, 2019;

Ehsani and Linnainmaa, 2022). This hypothesis tests the robustness of the momentum anomaly in the German stock market context, contributing to the broader literature on momentum strategies.

H3: The risk-adjusted returns of combined portfolios are higher than single-factor portfolios.

It is expected that the strategies will generate risk-adjusted returns exceeding those of the German market and single-signal portfolios, aligning with earlier European and global research such as (see e.g. Fama and French, 1998; Novy-Marx, 2013, 2015; Asness et al., 2013; Walkshäusl, 2014; Grobys and Huhta-Halkola, 2019). This hypothesis investigates the potential synergies between momentum and value strategies, proposing that their integration can lead to enhanced portfolio performance and reduced volatility, thus offering a more resilient investment approach.

1.3 Structure of the study

The second chapter begins with the theory of efficient markets, which is foundational to understanding the behaviors observed in financial markets. This chapter provides a comprehensive overview of the Efficient Market Hypothesis (EMH), discussing its implications for market efficiency and the potential for anomalies to exist. The third chapter details the asset pricing models such as CAPM and Fama-French factor models, which are essential for analyzing financial anomalies. The fourth chapter discusses the metrics used for evaluating portfolio performance, highlighting the methods for assessing the returns and risk-adjusted returns from different portfolios. This chapter includes an in-depth look at performance measures such as the Sharpe ratio, Treynor ratio, and Jensen's alpha.

The fifth chapter concentrates on financial market anomalies, with a particular focus on the value and momentum anomalies as well as their combination strategies, incorporating findings from prior research. It delves into the historical performance of these anomalies, the underlying reasons for their existence, and the potential benefits of integrating value and momentum strategies. The sixth chapter outlines the data and methodology used in the study, with a focus on signal construction. It details the sources of data, the criteria for stock selection, and the specific methods used to construct value and momentum signals. The empirical findings are presented in the seventh chapter, where the data is analyzed to conclude the value and momentum anomalies and their combining strategies. The final chapter summarizes the findings, limitations, and suggests areas for future research.

2 Efficient market hypothesis

The Efficient Market Hypothesis (EMH), theorized by the well-known economist and Nobel Laureate Eugene Fama in the 1960s, acts as a foundation for numerous financial theories. In academics, it provides a standard for exploring stock market anomalies like value and momentum anomalies. The core suggestion of the Fama (1970) theory is that stocks are continually priced at their intrinsic value, suggesting that achieving extraordinary gains through analytical strategies is largely coincidental. Essentially, it denotes that investors cannot buy stocks that are under or overvalued. EMH aims to explain why fluctuations in stock prices seem random, and as a result, future stock prices cannot be forecasted through past trends.

Theories such as Arbitrage Pricing Theory (APT) (Ross, 1976), the Capital Asset Pricing Model (CAPM) (Sharpe, 1964; Lintner, 1965), and Random Walk Theory (Fama, 1965) assume that markets are efficient and free from irregularities, such as anomalies. These theories posit that every investor has complete access to information and that their actions are rational. Market efficiency implies that all available information is immediately reflected in security prices, thus making the market information efficient. However, this idealized scenario often diverges from reality, as securities price movements can lag after new information is released. Additionally, investors' behavioral unpredictability and personal preferences can impact stock markets and asset pricing. These deviations from market efficiency are referred to as anomalies.

Fama (1970) states that efficiency can be defined through two key observations. Firstly, an efficient capital market is one where all private and public information is completely reflected in asset prices, preventing investors from securing market advantages through confidential or insider knowledge. Secondly, price levels should instantaneously adapt to newly released information. Once these conditions are met, resource allocation in capital markets is presumed efficient. Efficient Market Hypothesis is predicated upon the assumptions of a perfect market. According to Fama (1970), these include the absence of

transaction costs, freely available information, uniform investor expectations, and rational investor behavior, maintaining the market in an efficient equilibrium. In reality, these ideal conditions are rarely met, leaving the market not entirely efficient. Nevertheless, there is ample empirical evidence suggesting that markets, despite their imperfections, do exhibit efficiency as prices react to new information, although the degree to which they align with fundamental values remains uncertain.

A significant argument against the EMH is its oversight of the influence of human psychology and behavioral dynamics on market outcomes. Several research studies support the findings that the emotional and cognitive biases of investors can distort market prices, resulting in enduring trends of over or underperformance. Instances of global financial turmoil and irrational investors have exposed the limitations of the EMH, evidencing instances of mispricing in the financial markets.

Fama (1979) divides the levels of efficient markets into three categories which are weak, semi-strong, and strong forms. These forms look into the degree to which capital markets are efficient. When markets are completely efficient, all forms of efficient markets hold: strong, semi-strong, and weak. However, the presence of the weak form does not guarantee the presence of the strong form.

2.1.1 Weak-form of efficiency

Fama's (1970) weak form of efficiency argues that all past trading information, such as historical prices and volumes, is fully reflected in current market prices. Therefore, it is posited that no one can achieve excess returns consistently by using investment strategies based on historical price or volume data because the market has already assimilated this information into stock prices. Technical analysis, which relies heavily on patterns in historical data, is deemed ineffective under the weak form of EMH. Instead, investors might be dependent on fundamental analysis, which involves assessing a company's financial statements, management, competitive advantages, and market environment to

identify stocks that are undervalued or overvalued. The weak form of efficiency implies that while past price information is not functional for predicting future prices, fundamental analysis could still provide an edge in seeking above-average returns.

The study by DeBondt and Thaler (1985) provided a significant challenge to the weak form of the Efficient Market Hypothesis. The study found evidence of mean reversion in stock prices over the long term. They observed that stocks that had performed exceptionally well in the past three to five years tended to subsequently underperform, while those that had performed poorly tended to later outperform. This phenomenon, known as the overreaction hypothesis, suggests that investors tend to overreact to recent company performance, driving prices too high for winners and too low for losers. Over time, prices tend to revert to their mean, reflecting their intrinsic value more accurately. This mean-reverting tendency contradicts the weak form of EMH because it implies that investors could potentially earn above-average returns by adopting a contrarian investment strategy by buying stocks with poor recent performance and selling those with strong recent performance. If the weak form EMH were valid, such a systematic pattern of returns would not persist because past price movements would have no relationship with future price movements.

Research by Jegadeesh and Titman (1993) reveals that equities with strong historical performance yield larger returns and those with weaker historical performance yield lower returns in the three to twelve months preceding formation. This thesis places significant emphasis on the continued relevance of the momentum effect. Since past returns can be used to predict future returns, this also contradicts the weak form of efficiency. Furthermore, these patterns, such as return movements, go against market efficiency. Although studies like Fama and French (2018) attempted to explain these momentum returns in terms of risk, they have not been able to do so, as this thesis further examines.

2.1.2 Semi-Strong form efficiency

Fama's (1970) semi-strong form EMH extends the concept of market efficiency to all publicly accessible information. This includes, but is not limited to, historic market data, recent earnings reports, news releases, economic indicators, and other fundamental factors. Fama suggested that stock prices adjust so efficiently to new public information that it is impossible to benefit from trading on that information once it is released. Therefore, neither fundamental nor technical analysis would enable an investor to achieve consistent returns that outperform the market average, since the current prices would already reflect all known information. This form of EMH suggests that it is the unexpected events, not yet public, that will move the prices and therefore cannot be predicted or capitalized upon through analysis.

Event studies, which analyze asset price reactions before, during, and after specific events like earnings announcements, are used to test semi-strong efficiency. Fama et al. (1969) investigated whether stock splits were effectively reflected in stock prices after the event. Their findings supported the view of market efficiency, highlighting that stock splits often suggest a firm's potential for increased earnings. Subsequent research has adopted methodologies similar to Fama et al.'s to examine public announcements, consistently finding evidence in favor of market efficiency.

As the semi-strong market efficiency suggests stock prices instantaneously reflect all publicly accessible information, including accounting values reflected in high book-to-market ratios. These ratios are derived from company accounting records and published through earnings releases. Therefore, under the semi-strong efficiency hypothesis, the premise of value investing is that investors cannot achieve superior returns by purchasing stocks that are undervalued based on fundamental analysis should theoretically be ineffective. This is because any information that could indicate undervaluation is already incorporated into stock prices by the time it becomes public. Thus, according to this view, market prices always encapsulate such fundamental indicators, negating the potential for excess returns through strategies based on publicly available financial data. Fama and

French (1991, 1995, 2012) state that the value premium exists due to the higher risk in high book-to-market stocks. This raises questions about the viability of value investing in a market where information efficiency reaches the semi-strong level, challenging investors to find new methods or rely on yet-to-be public or private information to gain an investment edge.

2.1.3 Strong-form Efficiency

Fama (1970) states that the strong form of Efficient markets is the most rigid. It claims that stock prices fully reflect all public and insider information. This means that no one, not even company insiders with material, non-public information, can expect to consistently achieve above-average returns on their investments. In theory, strong-form efficient markets leave no room for any investors to consistently outperform the market because every piece of information, known or unknown to the public, is already incorporated into stock prices. However, Fama later acknowledged that in practice, strong-form efficiency may not hold due to various market anomalies and inefficiencies. Despite this, the strong form of the hypothesis is useful for analyzing and understanding market behavior and the dissemination of information.

Numerous studies demonstrate that insiders can and do earn significant abnormal returns from trading on non-public information, directly contradicting the notion of strong-form efficiency. For example, research by Jeng et al. (2003) found that insiders buying their own company's stock tend to outperform the market. A study by Grossman and Stiglitz (1980) argues that strong-form efficiency is impossible because if prices reflect all information, there would be no incentive for individuals to incur costs to acquire information, leading to a paradox where if everyone relied on the market is efficient, then the market would not be efficient at all. Lakonishok and Lee (2001) discovered that insider trading information might generate abnormal returns, regardless of its public knowledge status, even when considering associated costs. Their findings indicate that insider trading activity can be a pre-indicator of future price movements.

3 Asset pricing models

Asset pricing models are important in finance theory because they provide a frame for determining the expected or required return on an investment given its risk properties. The model's goal is to explain and predict how assets are priced and how expected returns are calculated. Asset pricing models fundamentally tie the concepts of risk and return, illustrating that assets with higher risk should provide higher expected returns to reward investors for bearing elevated risk. They often assume a state of market equilibrium, where the asset's price is stable when its expected return equals the required return as per the model.

3.1 Portfolio Theory

Portfolio Theory laid a foundation for modern portfolio management and the concept was introduced by Markowitz (1952). The theory introduced the concept of diversification and emphasized the importance of balancing risk against return. Central to Portfolio Theory is the idea that risk and expected return are the two most important factors in investment decision-making. Markowitz's theory suggests that an investor can achieve optimum portfolio allocation by considering these factors for individual securities and their correlation. The expected return for a portfolio can be calculated as follows:

$$E(R_p) = \sum_{i=1}^n w_i \times E(R_i), \quad (1)$$

Where $E(R_p)$ is the expected return of the portfolio. n represents the number of assets included, while w_i signifies the weight assigned to each security within the portfolio. $E(R_i)$ is the expected return of each asset. The w_p is equal to 1, meaning that the entire portfolio is accounted for. The risk of the portfolio is measured as variance, which is presented in the following formula for two asset portfolio:

$$\sigma_p^2 = \sigma_a^2 w_a^2 + \sigma_b^2 w_b^2 + 2w_a w_b \rho_{a,b} \sigma_a \sigma_b, \quad (2)$$

where σ_p^2 is the variance of the portfolio, w_a and w_b are the weights of security a and b . σ_a^2 and σ_b^2 are the variances of security a and b . $\rho_{a,b}$ is the correlation coefficient between the returns of security a and b . The correlation coefficient can vary between values -1 and 1, Where a coefficient of 1 means that the securities move in similar directions. A coefficient of -1 means that the securities move in opposite directions. A zero coefficient would indicate that there is no link between the securities. σ_a and σ_b are the standard deviations of security a and security b , respectively. The risk of the portfolio is usually described as the standard deviation which is $\sqrt{\sigma_p^2}$.

The key element in the theory is diversification. By investing in non-correlated assets, it is possible to decrease the overall risk of the portfolio. To present the most optimal portfolios regarding maximum optimal return for a given risk level Markowitz (1952) implements The Efficient Frontier. Figure 1. Illustrates The Efficient Frontier, the positively sloped curve depicting the risk and expected return. σ is the standard deviation and $E(R)$ is the expected return.



Figure 1. Ideal portfolio including a low-risk asset (Bodie et al., 2014)

Tobin (1958) adds a risk-free rate to the portfolio theory through the idea that an investor can construct a portfolio by mixing a risk-free asset with a portfolio of risky assets. The key insight from Tobin's addition is the concept of the Capital Market Line (CML), which plots the expected return of the portfolio against its standard deviation. The CML is a straight line that starts from the risk-free rate and is tangent to the efficient frontier as seen in Figure 1. This tangent portfolio is known as the market portfolio, and it represents the most efficient portfolio of risky assets. Tobin's theory demonstrates that by merging the risk-free asset with the market portfolio, investors can obtain any desired degree of risk and projected return. This combination provides for a more efficient asset allocation than would be possible with simply risky assets, according to Markowitz's original approach.

3.2 The capital asset pricing model

The capital asset pricing model (CAPM) is perhaps one of the most used asset pricing models in the financial literature, as well as one of the most important financial theories since Sharpe (1964), Lintner (1965), and Mossin (1966) developed it from Markowitz's (1952) portfolio theory and Tobin's (1958) separation theorem. According to Sharpe (1964), the model includes several assumptions which can be described as follows. Investors can borrow and loan at a risk-free interest rate for an indefinite period. Similar prospects exist among investors, and every bit of relevant information is publicly obtainable. The financial markets are in a state of equilibrium, where stocks trade at their fair value. All investors have access to the same investment options and finally, investors allocate the same amount of time to their investments.

The Capital Asset Pricing Model is described as a single-factor model that defines the connection between a security's expected return and risk. Sharpe (1964) demonstrates that the expected return on a security is equivalent to the risk-free rate combined with a risk premium based on the asset's beta. The risk-free rate is the return on a risk-free investment, such as a Euribor (Euro Interbank Offered Rate). The risk premium is the additional return that investors require for assuming the additional risk of investing in the asset. The risk premium is calculated using the asset's beta, which is a measure of its sensitivity relative to the overall market. The formula for the expected return of an asset, given its risk, is as follows:

$$E(r_i) = r_f + \beta_i(r_m - r_f), \quad (3)$$

where $E(r_i)$ is the portfolio i expected return, r_f is the risk-free rate, β_i is the i portfolio's beta coefficient, and $E(r_m)$ is the market portfolio's expected return. The β_i determines the sensitivity of portfolio i to the market factor. When there is a strong positive correlation between the stock and market returns, the predicted return is proportionate to the beta. A stock or portfolio with a higher beta is riskier and therefore has a higher expected return and vice versa. The formula for beta is as follows:

$$\beta_i = \frac{COV(R_i, R_{m,})}{\sigma^2(R_{m,})}, \quad (4)$$

Where β_i is the beta of the portfolio, $COV(R_i, R_{m,})$ is the covariance between the portfolio return and the market portfolio return. $\sigma^2(R_{m,})$ is the standard deviation of the market portfolio. Beta measures the sensitivity of the investment's returns to the overall market. A beta greater than 1 indicates that the asset is more volatile than the market, while a beta less than 1 indicates it is less volatile. Beta is the systematic risk of a security or portfolio relative to the overall market.

According to the Capital Asset Pricing Model, this systematic risk, which reflects an asset's sensitivity to economic fluctuations, determines the asset's expected return. The expected return is directly proportional to β , the measure of systematic risk. Therefore, securities that exhibit high correlations with the market's excess returns have higher β values, indicating higher systematic risk, which leads to higher expected returns. Conversely, securities with lower correlations to the market's excess returns have lower β values, implying lower systematic risk and consequently lower expected returns. CAPM posits that only systematic risk warrants a reward because it assumes that unsystematic risk can be entirely mitigated through effective diversification.

While the CAPM is common and still one of the most used methods for stock pricing, it has been challenged for its assumptions and limitations. The model is argued to be excessively simplified aversion for risky asset pricing. Other literature has acknowledged additional variables that the pricing model cannot explain. The CAPM assumes that markets are efficient, meaning that all known information is already reflected in stock prices. In an efficient market, any deviations from the expected return given by the CAPM formula would be arbitrated away. Therefore, on average, the alpha (α) should be zero. In addition, the CAPM, presupposes that investors are rational, and homogeneous and strive to maximize their returns, which is not always the case. Furthermore, the CAPM

does not account for the effect of taxes, transaction fees, and further factors on an asset's return (Sharpe, 1964).

Fama and French (1993) assert that the major weaknesses and concerns of the CAPM are such that it is incapable of explaining the market returns for small stocks. The statement adds that the estimation of Beta is also difficult since the best index to represent the market portfolio is not self-evident. To obtain comparable results, the choice of the right risk-free interest rate is also not always obvious. CAPM presupposes that investors can borrow and lend unlimited amounts at a risk-free rate, which is not practical since investors often face different borrowing and lending rates. Even Sharpe (1964) himself states that the assumptions can be constricting and unrealistic.

3.3 Fama-French three-factor model

Because the CAPM does not fully account for the observation of anomalies, more advanced multifactor asset pricing theories have been created. The model, developed by Fama and French, expands on the Capital Asset Pricing Model by adding two additional factors to explain stock excess returns beyond those described by market beta. These factors added to the CAPM, are size and value factors. According to Fama and French (1996), the size factor affects stock returns because smaller companies tend to have higher returns than larger companies. The value factor explains that Stocks with high book-to-market ratios tend to have higher returns than those with low book-to-market ratios. According to the model, the expected rate of return is determined with a formula that is as follows:

$$E(r_i) - r_f = \alpha_i + \beta_1(r_m - r_f) + \beta_2SMB + \beta_3HML + \epsilon_i, \quad (5)$$

where $E(r_i) - r_f$ is the Portfolio i 's expected return. β is the factor's coefficient sensitivity. $(r_m - r_f)$ is the market risk premium introduced in the CAPM. SMB is small-minus-big, which is a size factor based on a company's market capitalization. the factor

calculates the historic advantage of small-cap stocks over large-cap stocks. *HML* is high-minus-low signifying the return of high-book-to-market-ratio equities minus the return on low-book-to-market ratio stocks. The intercept α_i represents the abnormal return of the portfolio, often referred to as "alpha". It measures the portion of the return that is not explained by the model's three factors. ϵ_i is the zero-mean residual. All other notation is as previously defined.

Fama and French's (1993) regression analysis on 25 portfolios reveals that their three-factor model significantly outperforms the Capital Asset Pricing Model (CAPM) in explaining anomalies. This superior performance is anticipated, as the three-factor model was explicitly designed to capture key anomalies that CAPM fails to address. The three-factor model's ability to account for these anomalies is critical because CAPM, which only considers market risk, often falls short in explaining the cross-section of expected returns. For example, small-cap stocks and stocks with high book-to-market ratios tend to outperform what CAPM would predict, leading to persistent anomalies. Additionally, the two extra risk factors make the model more flexible than CAPM. Several studies show that the efficacy of the three-factor model in explaining stock market anomalies is critical evidence that these variables from the general order are alternatives for underlying risk (Fama & French, 1995).

The findings have prompted researchers to look for additional variables that can explain the returns through risk. Although the model is useful for comparing portfolio returns, it has faced criticism. Carhart (1997) argues that the Fama-French model, which includes market risk, size, and value factors, fails to capture other dimensions of risk that influence asset returns. For instance, Jegadeesh and Titman (1993) emphasized the significance of momentum as a critical factor. Furthermore, Fama and French (2012) note that the effectiveness of the three factors can vary over time and across different markets, suggesting that the model may not be universally applicable or stable.

3.4 Carhart four-factor model

Carhart (1997) enhances the Fama-French three-factor model with a β_4 *MOM* momentum factor. This addition to the formulation is based on momentum findings provided by Jegadeesh and Titman's (1993) paper. The classification of a stock as a winner or loser is determined by its historical accumulative returns. In other words, according to Carhart (1997), the factor is calculated by adding the returns of the market's top-performing stocks and subtracting the returns of the market's worst-performing stocks. The results of *MOM* demonstrate the additional returns achieved by a portfolio that engages in a long position on the best-performing stocks while shorting the worst-performing ones.

3.5 Fama-French five-factor model

Fama and French (2015) expanded the three-factor model to include five factors. Along with the original three components, the new model includes profitability and investment factors. The profitability *RMW* factor addresses the observation that more profitable companies tend to generate higher returns than less profitable ones, even after adjusting for other risk factors. This profitability effect challenges the traditional CAPM and earlier three-factor models, as it highlights the role of a firm's operational efficiency in driving stock returns. The investment *CMA* factor is based on the observation that companies with conservative investment policies tend to outperform those with aggressive investment strategies. The formula expands to as follows:

$$E(r_i) - r_f = \alpha_i + \beta_1(r_m - r_f) + \beta_2 \text{SMB} + \beta_3 \text{HML} + \beta_4 \text{RMW} + \beta_5 \text{CMA} + \epsilon_i, \quad (6)$$

Where *RMW* Robust Minus Weak factor captures the profitability premium, which is the difference in returns between firms with robust (high) and weak (low) profitability. Profitability is measured using operating profitability and divided by book equity. Firms with higher operating profitability are considered robust, while those with lower profitability

are considered weak. *CMA* factor captures the investment premium, which is the difference in returns between firms that invest conservatively and those that invest aggressively. Investment is measured by the growth in total assets. Firms with low asset growth are considered conservative, while those with high asset growth are considered aggressive. All other notation is as previously defined.

Empirical studies support the inclusion of the *RMW* factor. For instance, Novy-Marx (2013) demonstrated that profitability has predictive power for future returns, suggesting that profitable firms are less risky and thus command higher expected returns. The inclusion of the *RMW* factor in the Fama-French five-factor model enhances its ability to explain variations in stock returns, making it a more comprehensive tool for asset pricing and portfolio management. Evidence from Titman et al. (2004) found that firms with higher capital expenditures tend to have lower subsequent stock returns, indicating that aggressive investment strategies can lead to poorer performance. By incorporating the *CMA* factor, the Fama-French five-factor model more accurately explains variations in stock returns across different firms, making it a more robust framework for understanding and predicting asset prices.

3.6 Fama-French six-factor model

In response to both critical appraisal and empirical findings, Fama and French (2018) incorporated the momentum factor into their renowned five-factor model. Consequently, the evolution gave rise to what is now recognized as the six-factor model, which can be delineated in the following formulation:

$$E(r_i) - r_f = \alpha_i + \beta_1(r_m - r_f) + \beta_2SMB + \beta_3HML + \beta_4RMW + \beta_5CMA + \beta_6UMD + \epsilon_i, \quad (7)$$

where the *UMD* factor is constructed by ranking stocks based on their past performance, typically over the last 12 months, and then forming a portfolio that goes long on the top-

performing stocks and short on the bottom-performing stocks. The returns on this long-short portfolio constitute the UMD factor. Fama and French (2018) include the momentum factor to account for the anomaly in the markets. All other notation is as previously defined.

Empirical research strongly supports the momentum effect. Jegadeesh and Titman (1993) are among the first studies that documented this phenomenon, showing that a strategy of buying past winners and selling past losers generates significant abnormal returns. Their findings have been consistently confirmed by subsequent studies across different time periods and markets. The six-factor model is thought to be the best alternative for analyzing excess returns. The previously mentioned Carhart four-factor model lacks the additional elements found in the Fama-French five-factor model, and including the momentum factor is critical in explaining the excess returns. This could imply that because the momentum factor is included in the pricing model, the anomaly's impact and presence in the markets can be seen for extended periods.

4 Performance measures

Investment performance measures are crucial when making investment decisions as they allow investors, portfolio managers, and researchers to assess and compare the risk and return of different portfolios. The three key metrics in this are Jensen's Alpha, the Sharpe Ratio, and Treynor's Measure. Each provides a unique way to evaluate and understand risk-adjusted portfolio performance. These performance measures have been around for decades, and they remain relevant and widely used in contemporary finance literature and practice.

4.1 Jensen's alpha

Jensen's Alpha, often called CAPM alpha, is a robust indicator for evaluating performance while considering risk. It measures the average return a portfolio achieves above the expected return predicted by the Capital Asset Pricing Model. Introduced by Jensen (1968), this metric is widely used today to estimate a portfolio's performance by comparing actual returns to expected returns, given the portfolio's risk level. Jensen's Alpha can be calculated using the following formula:

$$\alpha = r_p - [r_f + \beta_i(r_m - r_f)], \quad (8)$$

where α is Jensen's alpha, r_p is the actual return of the portfolio, and the term $[r_f + \beta_i(r_m - r_f)]$ calculates the expected return of the portfolio according to the CAPM.

A positive Jensen's Alpha implies that the portfolio outperforms the expected return. A negative Jensen's Alpha, on the other hand, denotes underperformance. While Jensen's Alpha is a widely used performance metric, it should be used in combination with other indicators and not as the sole basis for investment decisions. As the metric is based only on the CAPM single factor market returns, it is an oversimplification. The benefit is that the results are widely comparable to other portfolios.

4.2 Sharpe ratio

The Sharpe Ratio, developed by Sharpe (1966), is a widely used measure for calculating the risk-adjusted return. The Sharpe Ratio serves as a metric for investors in explaining the relationship between an investment's return and its associated risk. This metric captures the average excess return over the risk-free rate per unit of volatility or total risk. The formula to compute the Sharpe Ratio is as follows:

$$\text{Sharpe ratio} = \frac{r_p - r_f}{\sigma_p}, \quad (9)$$

where r_p is the return of the portfolio, and r_f is the risk-free rate such as Euribor. σ_p is the portfolio's risk which is measured as the standard deviation of the portfolio returns. A higher Sharpe Ratio suggests a higher risk-adjusted return. A positive Sharpe Ratio indicates that the portfolio is expected to outperform the risk-free rate. A negative Sharpe Ratio implies that the investment's expected return is less than the risk-free rate. In general, investors consider a Sharpe Ratio of 1 to be good, 2 to be very good, and 3 to be excellent. However, these are general guidelines, and the Sharpe Ratio's interpretation may vary depending on other factors such as investment style and market conditions.

4.3 Treynor's measure

Treynor's Measure, devised by Jack L. Treynor, serves as a performance metric assessing the extent to which an investment adequately compensates its investors for each unit of systematic risk. The metric initially presented by Treynor (1965), seeks to identify how much excess return was generated for the risk involved in the investment, particularly focusing on the non-diversifiable or systematic risk. The formula for Treynor's measure is as follows:

$$\text{Treynor's Measure} = \frac{r_P - r_f}{\beta_P}, \quad (10)$$

where r_P represents the return achieved by the portfolio, while r_f denotes the prevailing risk-free rate of EU bonds. Additionally, β_P signifies the systematic risk inherent in the portfolio, providing insights into its sensitivity to market fluctuations.

A positive Treynor's Measure suggests that the investment is yielding returns above the risk-free rate for its associated risk level, while a negative value indicates underperformance relative to the risk-free rate. Higher Treynor's Measure implies that the investment provides better returns for each unit of systematic risk taken, which is desirable for investors. Unlike some other performance measures, Treynor's Measure specifically focuses on systematic risk, reflecting the vulnerability of the investment to movements in the overall market. Investors and portfolio managers leverage the Treynor Ratio to gauge whether a portfolio is providing adequate returns for the level of systematic risk involved.

Treynor's Measure relies heavily on beta, which assumes that historical market movements are reliable predictors of future ones. It is ideally suited for well-diversified portfolios, as it does not consider unsystematic risk. The selection of an appropriate risk-free rate can impact the ratio, sometimes making comparisons between different investments or periods challenging.

5 Anomalies

The efficient market hypothesis posits that in efficient markets, stock prices reflect all available relevant information. However, researchers have identified inconsistencies with rational pricing theory and noted the presence of mispricing opportunities throughout financial markets. While individual investors may act randomly, the market as a whole is expected to self-correct, as stock values ultimately reflect investors' perceptions of a company's worth. Once abnormalities are identified and studied, they often disappear or diminish because a substantial group of investors exploits these arbitrage opportunities (Loomes et al., 2003).

According to Fama and French (2008), anomalies are abnormal risk-adjusted returns, that are not captured by asset pricing models. This indicates that they can be statistically significant return patterns that vary from ordinary price reasoning. Anomaly is defined by Frankfurter and McGoun (2001) as irregularity and divergence from the overall order. Hou et al. (2020) state that the findings of these irregularities have led to the investigation of over 450 anomalies, and authors argue that nearly 65% of them cannot be replicated or their existence is statistically insignificant. Similar results are documented by Chordia et al. (2014) study on the US stock market, and the findings suggest that anomalies with excess returns disappear or at least become statistically insignificant before 1993.

The detection of anomalies is as crucial as attempting to uncover an economic reason for their appearance. This reasoning can result in doubt if anomalies represent either market inefficiency or if they reveal that the pricing models are inaccurate. Additionally, understanding the underlying economic reasons for anomalies can help in developing more robust investment strategies and improving market efficiency. As a result, numerous multifactor models have been developed to capture the variables that better explain excess stock market returns. As introduced before, these models aim to account for various risk factors and behavioral biases that traditional models may overlook, thereby providing a more comprehensive understanding of asset pricing.

5.1 Value

Value investing, a concept by Benjamin Graham and David Dodd (1934), is centered around investing in undervalued companies, commonly referred to as value stocks. These stocks are characterized by features that signal their undervaluation, primarily assessed through the book-to-market ratio. This ratio essentially compares a company's book equity value with its market value, offering a measure of its intrinsic worth versus its market price. One of the fundamental concepts introduced by Graham and Dodd (1934) is the margin of safety, which delineates the difference between a stock's intrinsic value and its market price. A greater margin of safety suggests a heightened potential for return.

Stattman (1980) conducted an important study that produced evidence to support the book-to-market anomaly. This concept of the book-to-market anomaly is also known as the value effect. An in-depth analysis of the effect reveals that companies with higher book-to-market ratios are often undervalued, whereas those with lower ratios tend to be overvalued. Together, these elements create an investment strategy that focuses on purchasing undervalued value stocks while simultaneously short-selling overvalued growth stocks. The study finds that in the U.S. stock market, book-to-market ratios and mean returns have a positive correlation. Similar outcomes in the U.S. markets were found by Rosenberg et al. (1985), Jaffe et al. (1989), Lakonishok (1994), and in the Japanese stock market by Chan et al. (1991). These studies employ ratios like earnings-to-price, book value-to-market value, and cash flow-to-price, which categorize stocks as either value or growth.

The recognition of the value anomaly gained acceptance following the comprehensive demonstration by Fama and French (1992) of a value premium within the U.S. stock market. They discovered that both size and the book-to-market ratio played a significant role in explaining the cross-section of average stock returns. Observing that small companies

with high book-to-market ratios generated higher returns, they hypothesized that size and book-to-market could serve as two additional risk factors beyond the market factor. This was further solidified by the introduction of the 3-factor model marking a significant advancement in the understanding of market dynamics. Fama and French (1992) suggest that markets are irrational in pricing companies' prospects. The consistent outperformance of value stocks over growth stocks may stem from investors and analysts overestimating the growth potential of growth stocks while being overly cautious about the prospects of value companies.

Initial skepticism regarding the value premium emerged throughout the tech bubble when the rise of growth stocks appeared to diminish the relevance of traditional valuation measures. This phenomenon was largely driven by an unsustainable increase in valuation multiples, which led to the bubble's burst in the early, as documented by Asness et al. (2000). Further study by Houge and Loughran (2006), identified no value premium within equity indices, mutual funds, and large-cap stocks.

Schwetz (2003) noted that the value anomaly vanished following the publication of research on the book-to-market ratio. This suggests that while market inefficiencies may have been present initially, they disappeared as the dissemination of research findings led to increased market efficiency. This occurred because practitioners capitalized on the anomaly until it no longer existed. Despite these challenges, the value effect has maintained broad acceptance across both academic and practical finance circles.

Asness et al. (2015) explore the intricacies of value investing, particularly focusing on the book-to-market (B/M) ratio as a measure of value. The study highlights that value stocks, characterized by high book-to-market ratios, have historically outperformed growth stocks over long periods. However, the paper also addresses misconceptions and emerging factors in the investment landscape. It critiques the limitations of relying solely on

the book-to-market ratio and emphasizes the benefits of incorporating multiple valuation metrics, such as earnings-to-price and cash-flow-to-price ratios, to create more stable and higher-performing value portfolios.

Research by Kok et al. (2017) finds little compelling evidence that value investing strategies, which mechanically apply ratios like book-to-market, deliver superior investment performance for U.S. equities. These strategies often identify firms with temporarily inflated accounting numbers rather than genuinely undervalued securities. Furthermore, the study reveals that the value premium is inconsistent across different periods. While there is some evidence of a premium in small-cap stocks, this is not observed consistently across all time frames or for large-cap stocks.

Fama and French (2020) analyze value premiums in the U.S. stock market from 1963 to 2019, revealing a significant decline in value premiums during the second half of the sample period. The study defines value stocks as those listed on the NYSE, AMEX, and NASDAQ with a book-to-market ratio at or above the 70th percentile of BM for NYSE stocks, while growth stocks are categorized as those with a BM ratio below the 30th percentile. The study finds a significant decline in value premiums in the latter half of the sample period, attributing this trend to shifts in market conditions that have led to lower expected returns for value stocks. These findings suggest that the traditional out-performance of value stocks may be less pronounced in more recent market environments.

5.2 Momentum

Momentum is one of the most researched anomalies and the fundamental idea of the strategy is to take advantage of the stocks that have positive or negative return trends. This trend is investigated from the stocks' historical price movement and the strategy is referred to as buying winners and selling losers. Momentum challenges the viability of the efficient market theory and is one of the most persistent anomalies that have shown

to achieve high returns while accounting for risk for long periods. According to Kelly et al. (2021), it is still an attractive strategy even though it is the subject of extensive research in finance and has a significant impact on financial markets.

De Bondt and Thaler (1985) developed the contrarian strategy, which is based on the idea that investors often overreact to news and information. To profit from corrections of these overreactions, the strategy suggests selling overperforming stocks and buying underperforming ones. This approach works over a longer period than other strategies, selecting stocks based on their performance over the past three to five years and holding them for a similar duration.

The first well-conducted paper about momentum investing as a strategy is presented by Jegadeesh and Titman (1993). In their research, they explore a momentum trading strategy in the U.S. stock market from 1965 to 1989. Their momentum portfolios are based on buying stocks that have performed well in the past (winners) and short-selling stocks that have performed poorly (losers). The winning portfolio will be selected from the top decile of stocks with the highest price appreciation over the specified period. The lowest decile will be selected from the stocks that have the greatest price decline throughout the period. The operation of the strategy ultimately depends on the top decile being used as a long position portfolio and the bottom decile being used as a short position portfolio, as shown.

Jegadeesh and Titman (1993) found that the momentum strategy made significant positive returns during the three-to-twelve-month holding period. After roughly twelve months, it began to generate negative returns. This return reversal suggests that momentum may be caused by short-term investor underreactions to firm-specific information. A portfolio created on stocks' relative performance over the previous 12 months and holding them in the portfolio for three months before reallocating produces the highest return. Similar findings regarding the momentum effect were reported by Chan

et al. (1996). They argue that prices react gradually to earnings surprises, resulting in both positive and negative price movements following the preliminary impact.

Jegadeesh and Titman (2001) used a sample period spanning from 1990 to 1998 to replicate the earlier study by using the same model. A replication of the initial research study provides additional evidence that the relative strength momentum strategy continued to yield profitable results, with monthly risk-adjusted returns of 1,39% from 1990 to 1998. The research additionally validates that the gains are not attributable to an increase in systematic risk. Significant momentum gains are also found in other momentum studies, such as Conrad and Kaul's (1998) analysis of the U.S. stock market from 1926 to 1989. The study further supports the findings of Jegadeesh and Titman (1993) and can be used as strong evidence to explain cross-sectional momentum, even though it employs a slightly different portfolio formation.

An explanation for the momentum anomaly, as theorized by Hong et al. (2000), is that information distribution among investors is often uneven, particularly for less-followed stocks. This results in delayed reactions to new information. The study further reveals that analysts tend to focus more on declining stocks than on successful ones. Their findings support the underreaction hypothesis, suggesting that momentum is driven by the gradual diffusion of firm-specific information. Consequently, momentum strategies tend to be more effective in cases where information is slower to reach the market.

From January 1990 to June 2002, Bird and Whitaker (2003) examined momentum returns in Germany, France, Italy, the Netherlands, Spain, Switzerland, and the United Kingdom. The study found that stocks with higher returns over the past 6 and 12 months continued to outperform when held for periods ranging from 1 to 12 months. However, this result was statistically significant at the 5% level only for Germany and the United Kingdom when applying a 6-6 momentum strategy.

Jegadeesh and Titman (1993) focus on the concept of cross-sectional momentum, a theory based on relative strength as a measure for stock selection initially proposed by Levy (1967). This theory suggests that investment decisions should be based on the relative performance of stocks compared to other stocks, indices, or equity benchmarks. Jegadeesh and Titman empirically validate this idea, demonstrating that stocks that have exhibited superior performance relative to others in the past tend to continue outperforming, while those with poorer relative performance are likely to underperform. This finding underscores the significance of relative performance in formulating effective investment strategies.

Moskowitz (2012) suggests time-series momentum as an alternative measure of the stock's performance. The paper highlights a key distinction which is that the time-series momentum strategy chooses stocks based on their past individual performance, unlike cross-sectional momentum, which compares stocks relative to others. This absolute momentum means that a stock's performance is measured against its history, not against peers or an index as in relative strength. Essentially, if a stock shows a positive price trend over the observed period, it exhibits positive absolute momentum. The greater this price change, the stronger the momentum is considered to be. Specifically, they document that past 12-month returns are strong predictors of future returns, showing persistence over 1 to 12 months, which partially reverses over longer horizons. This evidence supports the presence of time-series momentum across different markets and highlights its effectiveness. Similarly, Lim et al. (2018) study on time-series momentum in the U.S. markets from 1927 to 2017 documents strong evidence of time-series momentum in equities.

While momentum can cause excessive returns, it can also be a factor in a momentum crash through periods of extreme market volatility and unpredictability. Daniel and Moskowitz (2016) claim that markets going through long-term growth are the ideal environments for momentum. The situation may be reversed in bear markets, where asset values decline over a prolonged period. In contrast to their average performance, previous

winner stocks start to trend lower, while previous loser stocks typically trend higher. This can lead to a momentum crash during a short period when the market recovers. Barroso and Santa-Clara (2015) claim that the winners-minus-losers portfolio experienced significant losses after major crashes such as the Great Depression of 1930 and the 2008 financial crisis. These sudden momentum crashes during the Great Depression caused losses of over 90% in a matter of months. In the three months leading up to the 2008 financial crisis recovery, the winners-minus-losers portfolio experienced a loss of over 70%. Similar findings regarding reversals are evident in the study by Luo et al. (2021).

The study by Ehsani and Linnainmaa (2022) finds that the momentum observed in individual stocks can largely be attributed to momentum within factor returns. The results suggest that most factors exhibit positive autocorrelation, meaning that they tend to continue performing similarly in subsequent periods. This factor momentum effectively drives much of the momentum seen in individual stocks. An investor employing momentum strategies faces systematic risk because both winning and losing stocks in these trades tend to share similar factor exposures. Consequently, when the underlying factors remain stable, momentum strategies can be profitable. However, if these factors experience disruptions, the strategy may result in significant losses.

5.3 Combination of value and momentum

Asness (1997) discovers that although stocks characterized by value and high momentum yield higher average returns compared to those identified as growth and loser stocks, the difference in returns among growth and value stocks, when paired with momentum, is not significant. In addition, the returns for portfolios that lead (winner portfolios) remain essentially consistent whether they are based on value or growth. For portfolios that lag (loser portfolios), returns increase in combination with value. Given the negative correlation between the strategies, portfolios with high momentum tend to favor growth stocks, whereas value-oriented portfolios are inclined towards stocks with low momentum.

Fama and French (2012) investigated size, value, and momentum in international stock returns. Building on previous research, they identify value premiums in average returns across four regions: North America, Europe, Japan, and the Asia Pacific. Except for Japan, every region in the study has strong momentum returns. The study makes a significant contribution by examining the impact of firm size on international value and momentum returns. It is observed that value premiums are more significant for smaller stocks, except Japan. Moreover, the analysis outlines the differences in momentum returns, as shown by the spreads between winners and losers.

A more recent study by Asness et al. (2013), investigates the relationship and performance of value and momentum anomalies and also examines a combined strategy across eight asset classes and markets. The results show a high negative correlation between value and momentum. The study finds excess returns for both value and momentum across all examined markets and asset classes, except momentum in Japan. However, this exception in Japan is contextualized by the strong performance of value during the same period. A 50/50 weight combination of the two strategies improves returns and Sharpe ratios. In the European markets, a value and momentum mixing portfolio generated a 0,87 Sharpe ratio from 1974 to 2011, whereas value and momentum alone generated 0,42 and 0,55 Sharpe ratios, respectively.

Fisher et al. (2016) study a value and momentum strategy that is based on long only. In the context of the U.S. stock market, the study compares simpler mixing strategies to more complex combination strategies. The results show that both strategies outperform pure value and momentum, while the integrated strategy performs better than the mixing strategy. Each method resulted in higher Sharpe ratios relative to the market index for both small-cap and large-cap stocks. After accounting for transaction costs, value-oriented portfolios outperformed momentum-driven ones, primarily due to the slower signal movements and reduced portfolio turnover.

Cakici et al. (2013) study finds evidence of the value effect across all markets and the momentum effect in all regions except Eastern Europe. Their findings also highlighted a negative correlation between value and momentum strategies, aligning with earlier research. Similarly, Grobys and Huhta-Halkola (2019) observed this negative correlation in their assessment of the effectiveness of three momentum and value strategies; average rank, mixing, and integrating in the Nordic markets. Their research demonstrated that combining momentum and value strategies not only improved Sharpe ratios but also enhanced overall returns, underscoring the synergistic benefits of these combined approaches.

6 Data and methodology

This chapter details the data and methodology used to construct value and momentum portfolios, offering a comprehensive overview of the selection criteria, data sources, and statistical techniques utilized in the study.

6.1 Data

The sample consists of stocks included in the CDAX (Composite DAX), an extensive index of the German stock market that incorporates every company with ordinary shares listed on the Frankfurt Stock Exchange. It is a stock index managed by Deutsche Börse, providing a broad overview of the German equity market. The index encompasses all shares of the Prime Standard, General Standard, and Scale segments listed in the Frankfurt Stock Exchange. It includes various companies from many sectors, representing a holistic view of the German equity market. Unlike the DAX, which expanded from 30 to 40 major companies after 2021, the CDAX covers a wider spectrum of large, medium, and small-cap stocks in Germany. The historical returns for companies listed in the CDAX are sourced from the Thomson Reuters database and complemented by financial metrics from the Thomson Reuters Worldscope database. The converted European factor loadings are used from the Kenneth and French data base. The period is 240 months extending from July 2003 to June 2023. Similarly to Fama and French (2018), July is the starting month based on accounting information availability as typically by June, this financial information is comprehensively available. The 20-year period covers several growth and decline sentiments in the market.

Stocks from the banking, financial services, real estate investment, and non-life insurance sectors are excluded due to the unique nature of their financial statements, which necessitates a different analytical approach as highlighted in seminal works by scholars such as Fama and French (1992), and Asness et al. (2013). It also offers a more accurate comparison with other studies regarding value and momentum strategies because it is

standard procedure to leave out these groups. After the exclusions, the total number of stocks in the sample is 312. A prerequisite for inclusion in the sample is the availability of comprehensive data to compute all required variables. Furthermore, in cases of stock delisting, the return is conservatively estimated as zero, ensuring a standardized approach to handling such events.

Since listed companies report their financial results every quarter, ratios like book-to-market, quarterly market capitalization, and book value of equity are calculated from the quarterly results. The portfolios are created equally weighted with the CDAX total index returns. The total returns for each company within the sample incorporate the effect of dividends being reinvested back into the stock. All returns and measures are determined in euros as the CDAX is listed in Germany. As per previous research, the three-month Euribor is used as the risk-free rate. To prevent any negative risk-free rate during the examined period that could arise from using the 3-month Euribor, the risk-free rate is the average of the 3-month Euribor for the period.

Table 1. Descriptive statistics

Table 1 presents the descriptive statistics for the market portfolio and long-short portfolios. The market portfolio is represented by the CDAX stock index.

| | Descriptive statistics | | | | |
|----------------------------------|-------------------------------|-----------------------|-----------------------------|---------------|--------------------|
| | <i>Market</i> | <i>High minus low</i> | <i>Winners minus losers</i> | <i>Mixing</i> | <i>Integration</i> |
| Max number of stocks | 312 | 113 | 124 | 119 | 48 |
| Min number of stocks | 205 | 53 | 80 | 73 | 16 |
| Avg. number of stocks | 258 | 90 | 100 | 97 | 30 |
| Avg. market capitalization in B€ | 4,6 | 3,4 | 1,9 | 2,7 | 1,2 |

Table 1. Shows the descriptive statistics of the CDAX market index, the individual long-short value and momentum portfolios, and the two combining strategies which are the mixing and integration portfolios. The last row shows the average market capitalization in billions of euros. The Market portfolio has the largest average market capitalization at 4,6 billion euros, while the Integration portfolio has the smallest at 1,2 billion euros. These statistics indicate the composition and scale of each portfolio type, with the Market portfolio being the largest and most variable and the Integration portfolio being the most concentrated and smallest in average market capitalization.

6.2 Methodology

This methodology aligns with established practices in prior research, as highlighted in studies by Asness et al. (2013) and Grobys and Huhta-Halkola (2019). Every month, stocks are sorted into five groups (quintiles) according to their characteristics based on momentum and value. The top quintile is long, and the bottom quintile is short. Based on these classifications, portfolios are formulated employing various strategies like mixing and integrating.

The value (High minus low) signal is based on the Book-to-market ratio which is calculated as the book value of equity divided by market capitalization of equity. This measure is common for the value signal as seen in Fama and French (1993, 2015, 2018), Asness et al. (2013), and Fisher et al. (2016). The equity book value is updated on an annual basis, with a six-month delay from the conclusion of the calendar year. The value signals come from the past 12 months book-to-market ratios minus one allocation month. The market capitalization is updated quarterly. Missing book value of equity or market capitalization stocks are excluded from the sample. Value portfolios are reconstructed yearly meaning that the holding period is 12 months. This is due to the three-month cycle of quarterly reports which will limit the usage of monthly adjusting of the Book to Market ratios. The strategy involves buying stocks in the highest book-to-market quintile and

selling short those in the lowest quintile. The High Minus Low (HML) factor represents the difference in returns between these two quintiles.

The Winners Minus Losers (WML) signal derives from the total returns of the past 12 months, excluding the most recent month before allocation. The strategy involves buying stocks in the highest quintile (winners) and selling short those in the lowest quintile (losers). Momentum portfolios are adjusted monthly, aligning with prior studies. The WML factor is the return difference between the top quintile and bottom quintile.

The combined strategy, or the 50/50 mixing portfolio, leverages both value and momentum signals to diversify. This strategy involves allocating 50% of the portfolio to the High minus Low (HML) portfolio and the remaining 50% to the Winners minus Losers (WML) portfolio. By balancing these allocations, the strategy aims to capture the benefits of both value investing and momentum.

The process of creating an integrated portfolio involves combining momentum and value signals. A stock must simultaneously trigger the two signals to be included in the portfolio. To be more precise, a stock in the Value and Winners portfolio needs to be in the top quintile when compared to past returns and book-to-market ratios. To be included in the Growth and Losers portfolio, a stock needs to be in the lowest quintile, which is indicated by a high book-to-market ratio and lower historical returns.

7 Results

This section presents the results for momentum, value, and combined portfolios. The value and momentum portfolios are analyzed in two scenarios: one containing all stocks and another restricted to just the largest third of stocks by market capitalization. The combined strategy portfolios are evaluated using all companies in the sample. Based on prior research demonstrating the presence of value and momentum anomalies in European and global markets, it is reasonable to hypothesize that similar anomalies exist within the German market. Furthermore, it is expected that a combined strategies using both value and momentum factors will yield higher risk-adjusted returns than the individual strategies alone. Consequently, all the proposed strategies are expected to generate returns that surpass those of the broader market.

All returns are displayed to reflect the performance of the respective stock portfolios during the given period. Notably, any negative returns recorded for the Growth and Losers portfolios are, indicative of positive outcomes for short positions. In the tables, the parentheses "()" enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. Monthly returns are presented as absolute returns of the portfolio.

7.1 Single-signal portfolios

This section presents the results for the single-signal value and momentum portfolios. First, the value and momentum portfolio returns are presented for the whole sample. Furthermore, the size-based returns and portfolio characteristics are examined for large capitalization stocks in the sample where similar signals are used in order to determine the value and momentum effect for the third of the largest market capitalization.

7.1.1 Value returns

The results for the value-signal portfolios are presented below where the stocks are ranked based on their book-to-market ratio. The High factor includes the highest quintile of stocks based on their past 12-month average book-to-market ratio minus one allocation month. The Low factor is similarly constructed to the lowest quintile. The High minus Low factor presents the returns for the combination of High and Low factors. Every stock in a portfolio has the same weight, and this is maintained through yearly portfolio re-balancing.

Table 2. Value portfolios

The table 2. presents the performance of value portfolios spanning from July 2003 through June 2023. It presents the outcomes for both the (High) quintile and the (Low) quintile within the sample. The (HML) represents the differential returns of a long-short strategy involving these quintiles, essentially the returns of the long positions over the short positions. Additionally, the (Market) reflects the corresponding returns and statistical measures for the CDAX Market Index during the same period. The standard deviations are annualized. The parentheses "(") enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the un-adjusted, raw performance.

| | Value returns | | | |
|--------------------------|-------------------|----------------------|-----------------------|---------------|
| | <i>High</i> | <i>Low</i> | <i>High minus low</i> | <i>Market</i> |
| Monthly return | 0,83%** (2,42) | -0,01% (0,27) | 0,84%*** (3,82) | 0,68% |
| CAPM alpha | 0,28%* (1,71) | -0,61%*** (-3,43) | 0,79%*** (4,15) | |
| Standard deviation | 18,38% | 19,89% | 11,51% | 18,05% |
| Portfolio Beta | 0,78 | 0,89 | -0,10 | 1,00 |
| Sharpe ratio | 0,48 | -0,05 | 0,76 | 0,39 |
| Maximum monthly return | 14,52% | 15,43% | 12,90% | 16,08% |
| Maximum monthly drawdown | -20,56% | -25,49% | -10,84% | -19,78% |
| Average number of stocks | 45 | 46 | 91 | 258 |

The results indicate that the value effect is present in the German stock market, evidenced by a positive correlation between the book-to-market ratio and stock returns. The returns for both long-only and long-short portfolios are statistically significant at the 1% level. Firms with the lowest book-to-market ratios exhibit the lowest returns, which aligns with expectations. Although the returns for growth stocks are slightly negative, this finding is not statistically significant. Companies with the highest past book-to-market ratios achieve significantly higher returns compared to those with low book-to-market ratios. Notably, the portfolio that combines the long and short positions generates the highest significant raw return of 0,84%.

All portfolios generate significant alpha and the highest alpha is in the long-short portfolio. This means that the portfolios have performed better than the benchmark in terms of the level of their risk. The Sharpe ratio of the Value portfolio exceeds that of the market, suggesting superior performance concerning volatility. Furthermore, the Sharpe ratio shows an improvement in the High Minus Low portfolio, significantly surpassing the market in terms of returns relative to the portfolio volatility. This is mainly because it has a substantially lower standard deviation compared to the value, growth, and market index. The standard deviations of the High and Low factors are comparable, but the growth stocks are slightly more volatile. The maximum monthly drawdown is most severe for growth stocks, reaching -25.49%, whereas the long-short portfolios experience a significantly lower drawdown of only -10.84%. The results indicate that, unlike the findings of Fama and French (2020) for U.S. equities, the value anomaly has not diminished in the German market during the 2000s.

Table 3. Value top-third returns

The table 3. details the performance of the top third value portfolios spanning from July 2003 through June 2023. The table includes the top third of the largest companies in the sample. The standard deviations are annualized. The parentheses "()" enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the unadjusted, raw performance.

| | Value top third | | |
|--------------------|-------------------|-------------------|-----------------------|
| | <i>High</i> | <i>Low</i> | <i>High minus low</i> |
| Monthly return | 1,04%** (2,37) | 0,58%* (1,91) | 0,46%* (1,72) |
| CAPM alpha | 0,32% (1,32) | -0,01% (-0,06) | 0,23% (1,21) |
| Standard deviation | 23,58% | 18,81% | 17,10% |
| Portfolio Beta | 1,08 | 0,86 | 0,24 |
| Sharpe ratio | 0,48 | 0,31 | 0,26 |

For the largest third of companies in the sample, the long portfolio achieves statistically significant returns at the 5% level which are higher returns than for the total sample. This indicates that large market capitalization stocks, characterized by high book-to-market ratios, yield greater returns compared to the broader selection of high book-to-market stocks. However, this advantage does not extend to large-cap stocks with low book-to-market ratios, where shorting does not prove to be as effective. When applied to the top third of the sample, the effectiveness of the long-short portfolio strategy is weaker compared to the results for the entire sample, but the results are statistically significant at a 10% level. The large-cap stocks demonstrate elevated standard deviations, potentially resulting from a smaller pool of stocks and reduced diversification. While all Sharpe ratios are relatively low, the High portfolio's ratio indicates that it provides a slightly better risk-adjusted return than the other two. The High portfolio, focusing on large-cap stocks, exhibits a higher beta, whereas the long-short portfolio maintains a non-negative beta, diverging from the trend observed across all stocks.

7.1.2 Momentum returns

The results for the momentum portfolios are presented below where the stocks are ranked based on their past returns. The Winners factor includes the highest quintile of stocks based on their past 12-month average returns ratio minus one allocation month. The Losers factor is similarly constructed to the lowest quintile of the sample stocks. The Winners minus Losers factor presents the returns for the combination of winners and Losers factors. Every stock in a portfolio has the same weight, and this is maintained through monthly portfolio rebalancing.

Table 4. Momentum returns

Table 4. details the performance of momentum portfolios spanning from July 2003 through June 2023. It presents the outcomes for both the (Winners) quintile and the (Losers) quintile within the sample. The (WML) represents the differential returns of a long-short strategy involving these quintiles, essentially the excess returns of the long positions over the short positions. Additionally, the (Market) reflects the corresponding returns and statistical measures for the CDAX Market Index during the same period. The standard deviations are annualized. The parentheses "(")" enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the unadjusted, raw performance.

| Momentum returns | | | | |
|--------------------------|--------------------|----------------------|---------------------------------|---------------|
| | <i>Winners</i> | <i>Losers</i> | <i>Winners minus losers</i> | <i>Market</i> |
| Monthly return | 1,08%*** (3,30) | -0,54% (-1,30) | 1,62%*** (5,24) | 0,68% |
| CAPM alpha | 0,55%*** (2,71) | -1,21%*** (-3,86) | 1,67%*** (5,62) | |
| Standard deviation | 17,52% | 24,38% | 16,59% | 18,05% |
| Portfolio Beta | 0,74 | 0,99 | -0,24 | 1,00 |
| Sharpe ratio | 0,68 | -0,31 | 1,11 | 0,39 |
| Maximum monthly return | 15,45% | 25,22% | 16,81% | 16,08% |
| Maximum monthly drawdown | -16,72% | -29,88% | -20,42% | -19,78% |
| Average number of stocks | 50 | 50 | 100 | 258 |

The results support the theory that past stock returns can predict future returns. The momentum effect is relevant in the German markets and during the period momentum strategy gained significant returns. The winners portfolio gained a 1,08% monthly average return which is statistically significant at a 1% level. The Losers portfolio also gained a 0,54% monthly return, which is statistically insignificant. The Winners minus Losers portfolio gained 1,62% average return with 1% significance levels which clearly shows that the spread between winners and losers was widened with the combination of long and short positions. All strategies gained significant CAPM alpha on 1% levels. The portfolio of winners minus losers achieved the highest gains, with an alpha of 1,67%, surpassing the raw return. This is possible due to the negative beta that the portfolio is experiencing. This also confirms that the returns are not coming from increased market risk as the beta of the long-short portfolio is negative.

The Sharpe ratios of the winners and long-short portfolios are considerably higher than the market's Sharpe ratio of 0,39, suggesting a better risk-adjusted return. The Sharpe ratio for the winners portfolio is 0,68, while the ratio for the winners-minus-losers portfolio is 1,11. The most volatile portfolio is the losers portfolio, characterized by the highest standard deviation of 25%. Despite its overall good performance, the momentum strategy experienced some significant downturns during the period, as noted in earlier studies. The losers portfolio experienced the highest maximum monthly return of 25.22%, but it also faced the greatest maximum drawdown. In comparison, the WML portfolio had a maximum drawdown of -20.42%. The results indicate that the momentum anomaly remains evident in equity markets, consistent with the findings of studies such as Grobys and Huhta-Halkola (2019) and Ehsani and Linnainmaa (2022).

Table 5. Top third momentum returns

Table 5. details the performance of the top-third momentum portfolios spanning from July 2003 through June 2023. The table includes the top third of the largest companies in the sample. The standard deviations are annualized. The parentheses "(") enclose the T-statistics associated with the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the unadjusted, raw performance.

| Momentum top-third | | | |
|---------------------------|--------------------|---------------------|-----------------------------|
| | <i>Winners</i> | <i>Losers</i> | <i>Winners minus losers</i> |
| Monthly return | 1,36%*** (4,05) | 0,03% (0,20) | 1,33%*** (4,53) |
| CAPM alpha | 0,81%*** (3,91) | -0,34%** (-2,43) | 1,06%*** (3,86) |
| Standard deviation | 17,97% | 12,47% | 15,70% |
| Portfolio Beta | 0,78 | 0,48 | 0,30 |
| Sharpe ratio | 0,84 | -0,06 | 0,95 |

Within the context of the largest third of firms by market capitalization, both winner quintile and WML portfolio constructions have generated statistically significant returns and alpha at a 1% level. This outcome suggests that winner stocks with substantial market caps and exhibiting high returns over the preceding 12 months are likely to outperform when compared to a more comprehensive stock universe. Nevertheless, this observed outperformance is not universally applicable as it appears less pronounced for large-cap stocks with lower historical performance, where employing short positions fails to be equally beneficial. Additionally, the WML factor appears to be less effective with the top-third companies compared to stocks across all market capitalizations.

The Sharpe ratio associated with the top third's winners portfolio significantly exceeds the corresponding Sharpe ratio and alpha of the entire sample, highlighting the strategic quality of focusing on high-performing large-cap stocks. Yet, it is noteworthy that the

Sharpe ratio or the alpha of the long-short strategy within this segmented group does not surpass that of the entire sample.

7.2 Combination portfolios

This section details the results of combining value and momentum strategies and evaluates the performance of these combined approaches. Initially, it presents the results for the mixing approach, where the portfolio is constructed with a 50/50 allocation to value and momentum. Subsequently, it assesses the performance of the integrating portfolios, which require stocks to simultaneously exhibit both value and momentum signals.

7.2.1 Mixing value and momentum

This section examines the results of a straightforward mixing approach, wherein the portfolio is equally divided between value and momentum. The table below presents the outcomes for portfolios that combine single-signal momentum and value portfolios. This is achieved by constructing a portfolio that is composed of a 50% allocation to stocks exhibiting momentum signals and a 50% allocation to stocks with value signals. It is expected that the adoption of this mixed strategy could lead to reduced standard deviations, attributable to enhanced diversification across the two methodologies. Consequently, this approach is likely to yield superior Sharpe ratios in comparison to deploying either the value or momentum strategies individually. The 50/50 allocation will lead to returns being the average of the two strategies.

Table 6. Mixing value and momentum returns

Table 6. presents the performance of the value and momentum mixing portfolios spanning from July 2003 through June 2023. It presents the outcomes for both the (High and Winners) quintile and the (Low and Losers) quintile within the sample. The (Mixing) represents the differential returns of a long-short strategy involving these quintiles, essentially the excess returns of the long positions over the short positions. Additionally, the (Market) reflects the corresponding returns and statistical measures for the CDAX Market Index during the same period. The standard deviations are annualized. The parentheses "(")" enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the unadjusted, raw performance.

| Mixing returns | | | | |
|--------------------------|-------------------------|-----------------------|--------------------|---------------|
| | <i>High and winners</i> | <i>Low and losers</i> | <i>Mixing</i> | <i>Market</i> |
| Monthly return | 0,95%*** (2,96) | -0,27% (-0,77) | 1,22%*** (6,04) | 0,68% |
| CAPM alpha | 0,42%** (2,32) | -0,91%*** (-3,71) | 1,22%*** (6,37) | |
| Standard deviation | 17,31% | 21,38% | 10,84% | 18,05% |
| Portfolio Beta | 0,76 | 0,94 | -0,18 | 1,00 |
| Sharpe ratio | 0,60 | -0,20 | 1,25 | 0,39 |
| Maximum monthly return | 14,99% | 20,32% | 10,22% | 16,08% |
| Maximum monthly drawdown | -17,79% | -27,68% | -12,38% | -19,78% |
| Average number of stocks | 96 | 97 | 192 | 258 |

The findings indicate that while the returns for the mixing portfolios surpass those of the Value portfolios, they fall short of the returns achieved by the individual Momentum portfolios. This outcome aligns with expectations, given that Momentum strategies outperformed Value portfolios in terms of returns. The long portfolio generates raw returns of 0,95% with 1% statistical significance while the short portfolio generates 0,27% returns that are not statistically significant. Mixing portfolio monthly returns are 1,22% with 1% statistical significance. Short and mixing portfolios generate alpha on a 1% significance

level. When examining risk-adjusted returns, the mixing strategy demonstrates improvement for the lowest quintile in comparison to both individual value and momentum strategies. Furthermore, the Sharpe ratio for the mixing portfolio outperforms that of each long and short portfolio, suggesting its superior risk-adjusted performance. The mixing portfolio generates a Sharpe ratio of 1,25, the highest among all the portfolios analyzed in this study. While the returns of the mixing portfolio are not exceptionally high, its low volatility significantly enhances its performance. This combination of moderate returns and minimal fluctuations makes the mixed portfolio a solid performer, offering a favorable risk-reward balance.

The mixing of value and momentum enhances the extreme ends of this portfolio as the Maximum monthly drawdown is only -12,38%. In addition, the maximum monthly return is also low at 10,22% for the long-short portfolio. The growth and losers portfolio is mainly driven by the momentum effect as the growth stocks alone were not effective. The findings suggest that the mixing enhances the Sharpe ratios although the total returns of the mixing portfolio are lower than those of the single-factor Momentum portfolio. This improvement is most likely attributed to the low correlation between the value and momentum strategies.

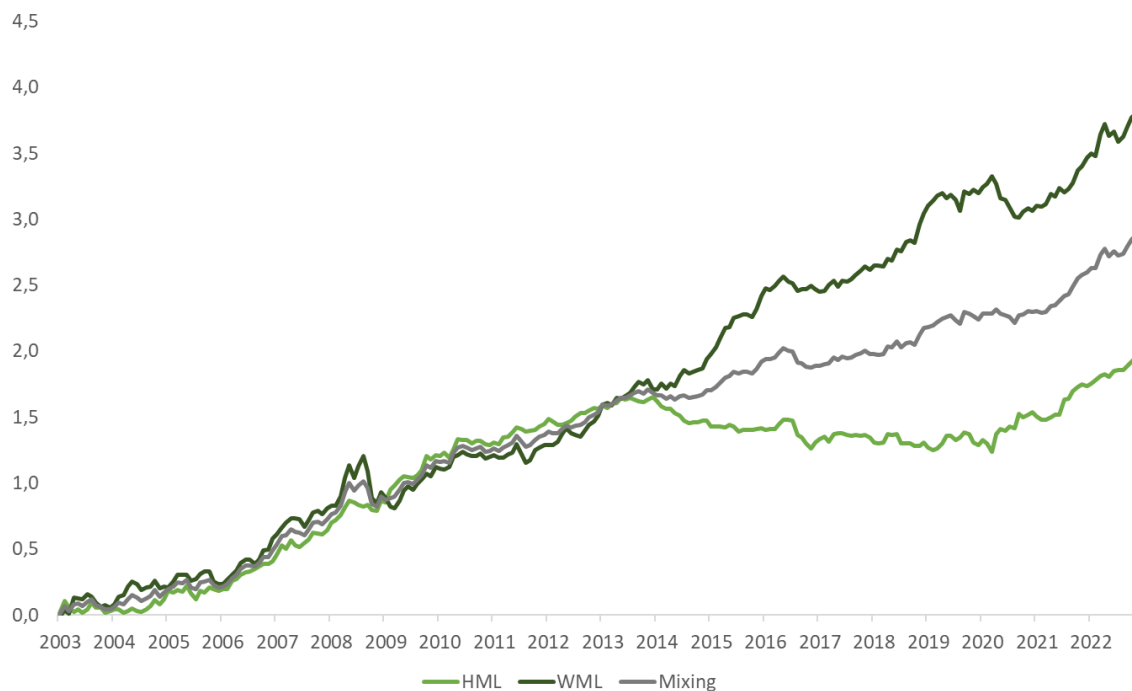


Figure 2. Cumulative returns of value, momentum, and mixing strategy

Figure 2. displays the cumulative returns of the portfolios based on the Value minus Growth strategy, Winners minus Losers strategy, and a mixing portfolio. The chart reveals that until 2014, the Value and Momentum strategies generated comparable returns. Post-2014, the chart indicates a divergence where the Value strategy begins to underperform relative to the momentum. This divergence can be attributed to the post-2008 period, when the economic environment favored high-innovation sectors, leading to substantial returns for growth stocks.

7.2.2 Integrating value and momentum

The table below displays the results for portfolios created by combining value and momentum signals. These portfolios contain stocks that exhibit both signals. For example, a value-winner portfolio contains stocks that exhibit both the value and winner signals, whereas a growth-loser portfolio contains stocks that exhibit both the growth and loser signals.

Table 7. Integrating value and momentum returns

Table 7. presents the performance of the value and momentum integration portfolios spanning from July 2003 through June 2023. It presents the outcomes for both the (High and Winners) quintile and the (Low and Losers) quintile within the sample. The (Integration) represents the differential returns of a long-short strategy involving these quintiles, essentially the excess returns of the long positions over the short positions. Additionally, the (Market) reflects the corresponding returns and statistical measures for the CDAX Market Index during the same period. The standard deviations are annualized. The parentheses "(")" enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the unadjusted, raw performance.

| Integrating portfolio returns | | | | |
|--------------------------------------|-------------------------|-----------------------|--------------------|---------------|
| | <i>High and winners</i> | <i>Low and losers</i> | <i>Integration</i> | <i>Market</i> |
| Monthly return | 1,10%*** (2,70) | -0,96%** (-1,98) | 2,06%*** (3,87) | 0,68% |
| CAPM alpha | 0,59%** (1,96) | -1,59%*** (-3,41) | 2,09%*** (3,98) | |
| Standard deviation | 21,77% | 30,10% | 28,53% | 18,05% |
| Portfolio Beta | 0,70 | 0,92 | -0,21 | 1,00 |
| Sharpe ratio | 0,55 | -0,42 | 0,83 | 0,39 |
| Maximum monthly return | 19,83% | 34,64% | 24,83% | 16,08% |
| Maximum monthly drawdown | -18,12% | -35,26% | -32,40% | -19,78% |
| Average number of stocks | 10 | 21 | 30 | 258 |

The results suggest that integrating value and momentum signals substantially enhances returns. The portfolio consisting of high-value and winning stocks yields monthly returns of 1,10% at a 1% significance level, while the portfolio consisting of growth and losing stocks earns monthly returns of 0,96% at a 5% significance level. Consequently, this combination results in a long-short portfolio delivering a compelling monthly return of 2,06% at a 1% significance level, translating to an annual absolute return of 24,72%. The integration method proves to be effective, as the long and short portfolios are generating nearly identical monthly returns. Alphas are statistically significant at the 1% level for

both the low and losers portfolio and the integration portfolio, with the integrated portfolio generating a 2,09% monthly alpha. This statistical significance indicates that systematic risk alone cannot explain these excess returns.

The low and losers portfolio exhibits the highest standard deviation, whereas the high and winners portfolio has a much smaller standard deviation. The integration of value and momentum results in a higher standard deviation than the mixing method. Although the integration portfolio produces a high Sharpe ratio of 0,83, higher standard deviations lead to lower Sharpe ratios compared to mixing portfolios. Therefore, while the integration strategy results in greater returns, it loses to the mixing portfolio in risk-adjusted terms due to high volatility. This higher volatility could be attributed to the low number of stocks in the portfolio compared to other strategies. The maximum monthly return of 24,83% and the drawdown of -32,40% reflect a considerably higher spread and extreme values, which are expected given the high standard deviations.

7.3 Performance comparison

This section provides a detailed conclusion of the results for the long-short portfolios, summarizing their performance and key findings. Additionally, it highlights the Fama-French 5-factor and 6-factor betas and alphas. The Fama-French factor alphas provide insights into the excess returns generated by a portfolio beyond what can be explained by the Fama-French factors. In addition, the section covers the correlations between the strategies.

Table 8. Long-short portfolios

Table 8. presents the returns and characteristics for all long-short portfolios from July 2003 to June 2023. The standard deviations are annualized. The parentheses "()" enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels. The monthly returns reflect the unadjusted, raw performance.

| | Long-short portfolios | | | |
|-------------------------------------|------------------------------|-----------------------------|--------------------|--------------------|
| | <i>High minus low</i> | <i>Winners minus losers</i> | <i>Mixing</i> | <i>Integration</i> |
| Monthly return | 0,84%*** (3,82) | 1,62%*** (5,24) | 1,22%*** (6,04) | 2,06%*** (3,87) |
| CAPM alpha | 0,79%*** (3,75) | 1,67%*** (5,62) | 1,22%*** (6,37) | 2,09%*** (3,98) |
| Standard deviation | 11,51% | 16,59% | 10,84% | 28,53% |
| Portfolio Beta | -0,10 | -0,24 | -0,18 | -0,21 |
| Sharpe ratio | 0,76 | 1,11 | 1,25 | 0,83 |
| Treynor's measure | 0,10 | 0,19 | 0,14 | 0,26 |
| Maximum monthly return | 12,90% | 16,81% | 10,22% | 24,83% |
| Maximum monthly drawdown | -10,84% | -20,42% | -12,38% | -32,40% |
| Average number of stocks | 90 | 100 | 192 | 30 |
| Average market capitalization in B€ | 3,4 | 1,9 | 2,7 | 1,2 |

The Integration portfolio has been observed to yield the most substantial monthly returns and the highest monthly alpha. However, this portfolio also exhibits a notably elevated standard deviation compared to its counterparts, resulting in a comparatively lower Sharpe ratio relative to the Momentum and Mixing portfolios. Although the Mixing portfolio underperforms the Momentum and Integration portfolios in terms of returns and alpha generation, it compensates by offering the most favorable Sharpe ratio,

likely due to its lower standard deviation of 10.22%. Furthermore, the Integration portfolio has the highest Treynor's measure, indicating that it achieves the most substantial returns relative to its level of systematic risk.

Every long-short portfolio has been identified as holding a negative beta compared to the market, indicating an inverse relationship with market movements. The integration portfolio has the highest monthly return and drawdown. Additionally, the Integration portfolio maintains a notably smaller selection of stocks. This smaller selection of stocks comes because of the strong criteria of stock inclusion, requiring stock to exhibit indications from both value and momentum signals. Consequently, the stock count within this portfolio is subject to significant fluctuations, depending on the dynamic nature of stock characteristics such as book-to-market ratios and past returns.

Table 9. Fama-French six-factor regression coefficients, long-short portfolios

Table 9. presents the Fama-French factor betas for the single-signal and two-signal portfolios from July 2003 to June 2023. These factor betas follow the Fama-French 5- and 6-factor European model proposed by Fama-French (2015,2018), converted from USD to local currency according to Gluck et al. (2020). The parentheses "(") enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels.

| Fama-French factor betas | | | | |
|---------------------------------|-----------------------|-----------------------------|-------------------|--------------------|
| | <i>High minus low</i> | <i>Winners minus losers</i> | <i>Mixing</i> | <i>Integration</i> |
| Mkt-RF | -0,14*** (-2,97) | 0,03 (0,45) | -0,06 (1,61) | 0,07 (0,55) |
| SMB | 0,09 (0,74) | -0,27* (-1,85) | -0,09 (-0,90) | -0,27 (-0,91) |
| HML | 0,47*** (2,71) | -0,01 (-0,03) | 0,21* (1,80) | -0,23 (-0,59) |
| RMW | 0,27 (1,30) | 0,45 (1,75) | 0,36** (2,47) | 0,47 (0,89) |
| CMA | 0,31 (1,57) | 0,55** (2,30) | 0,43*** (2,67) | 0,99** (2,03) |
| MOM | 0,08 (1,09) | 0,72*** (8,22) | 0,39*** (6,64) | 0,65*** (3,80) |

The table above presents the Fama-French factor betas for long-short portfolio strategies over the period from July 2003 to June 2023. These factor betas help in understanding the sensitivities of each portfolio to different risk factors within the Fama-French model. The betas suggest that the High minus low portfolio is primarily influenced by the HML factor, which aligns with expectations. The Winners minus losers portfolio is largely explained by the WML factor, as anticipated, but the CMA factor also contributes to its returns. The RMW factor predominantly drives the Mixing portfolio. The Integration portfolio is mostly influenced by the CMA factor, but also substantially by the WML and HML factors, which is consistent with expectations.

Table 10. Fama-French 5- and 6-factor alphas, long-short portfolios

Table 10. shows the Fama-French factor alphas for long-short portfolios between July 2003 and June 2023. These factor alphas follow the Fama-French 5- and 6-factor European model proposed by Fama-French (2015,2018), converted from USD to local currency according to Gluck et al. (2020). The returns are monthly. The parentheses "(") enclose the T-statistics associated with both the returns and alphas. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels.

| Fama-French factor alphas | | | | |
|----------------------------------|-----------------------|-----------------------------|------------|--------------------|
| | <i>High minus low</i> | <i>Winners minus losers</i> | <i>Mix</i> | <i>Integration</i> |
| CAPM alpha | 0,79%*** | 1,67%*** | 1,22%*** | 2,09%*** |
| t | (3,75) | (5,62) | (6,37) | (3,98) |
| Fama-French 5-factor | 0,68%*** | 1,45%*** | 1,07%*** | 1,87%*** |
| t | (3,38) | (4,89) | (5,50) | (3,40) |
| Fama-French 6-factor | 0,61%*** | 0,89%*** | 0,77%*** | 1,34%** |
| t | (2,88) | (3,26) | (4,08) | (2,41) |

Significant alphas are observed across all single- and two-signal long-short portfolios, with the value portfolio exhibiting the lowest CAPM alpha, and the integration portfolio generating the highest, as previously mentioned. This pattern continues in the Fama-French 5-factor model, where all portfolios yield significant alphas. However, the model

struggles to fully account for the returns of these portfolios, indicated by the relatively high alphas. The market factor ($R_m - R_f$) creates the most substantial influence on the five-factor alphas.

When incorporating the momentum factor into the factor model, the 6-factor model leads to a notable decrease in alphas, which remains significant at the 1% level. This suggests that the momentum factor plays a crucial role in explaining the excess returns of these portfolios, particularly affecting the Momentum and integration portfolios due to their inherent momentum exposure. Nonetheless, the Fama-French factor models do not fully account for their excess returns, which aligns with studies across international markets and Europe.

Table 11. Correlation matrix, all portfolios

Table 11. presents the correlation coefficients between all portfolios examined in this study. Each value in the table represents the correlation coefficient between a pair of portfolios, which can range from -1 to 1. Positive Correlations from 0 to 1 Indicate that the portfolios tend to move in the same direction, while negative Correlations from -1 to 0 Indicate that the portfolios tend to move in opposite directions. The parentheses "(")" enclose the T-statistics associated with the correlations.

| Correlation matrix | | | | | | | | | |
|---------------------------|------------------|------------------|----------------------|------------------|------------------|------------------|------------------|--------------------------|---------------|
| | <i>Value</i> | <i>Growth</i> | <i>Win- ners</i> | <i>Losers</i> | <i>HML</i> | <i>WML</i> | <i>Mix</i> | <i>Integra- tion</i> | <i>Market</i> |
| Value | 1,00 --- | | | | | | | | |
| Growth | 0,82 (22,27) | 1,00 --- | | | | | | | |
| Winners | 0,85 (25,82) | 0,85 (25,00) | 1,00 --- | | | | | | |
| Losers | 0,82 (22,21) | 0,86 (25,52) | 0,73 (16,62) | 1,00 --- | | | | | |
| HML | 0,18 (2,81) | -0,42 (-7,84) | -0,10 (-1,55) | -0,18 (-2,87) | 1,00 --- | | | | |
| WML | -0,30 (-4,85) | -0,37 (-6,17) | -0,02 (-0,32) | -0,70 (-9,51) | 0,16 (2,64) | 1,00 --- | | | |
| Mix | -0,14 (-2,12) | -0,51 (-9,32) | -0,07 (-1,33) | -0,63 (-9,88) | 0,66 (13,23) | 0,85 (25,12) | 1,00 --- | | |
| Integration | -0,03 (-0,70) | -0,27 (-4,16) | 0,02 (0,24) | -0,50 (-8,28) | 0,44 (7,45) | 0,74 (16,89) | 0,80 (20,67) | 1,00 --- | |
| Market | 0,77 (18,61) | 0,80 (20,90) | 0,77 (18,37) | 0,73 (16,50) | -0,16 (-2,54) | -0,26 (-4,23) | -0,29 (-4,64) | -0,14 (-2,14) | 1,00 --- |

The results of the correlation matrix suggest that the HML and WML portfolios do not have a negative correlation as indicated by previous studies such as Assnes et al. (2013). However, the correlation between the strategies remains close to zero over the entire period. When focusing specifically on the period after 2014, the correlation becomes slightly negative. The portfolios with the highest correlations are observed between Value and winners, Growth and losers, and Mix and WML strategies, each showing a correlation of 0,85. The strongest negative correlation is between losers and WML and between losers and mixing strategies. The portfolios show statistically significant results for the majority of portfolios except for WML and Winners, Mix and Winners, and integration and Winners portfolios. As previously mentioned, the long-short portfolios exhibit a low correlation with the market index. Notably, the correlation coefficients for these portfolios are negative across the board, which may contribute to enhanced diversification benefits and the potential for reduced portfolio risk.

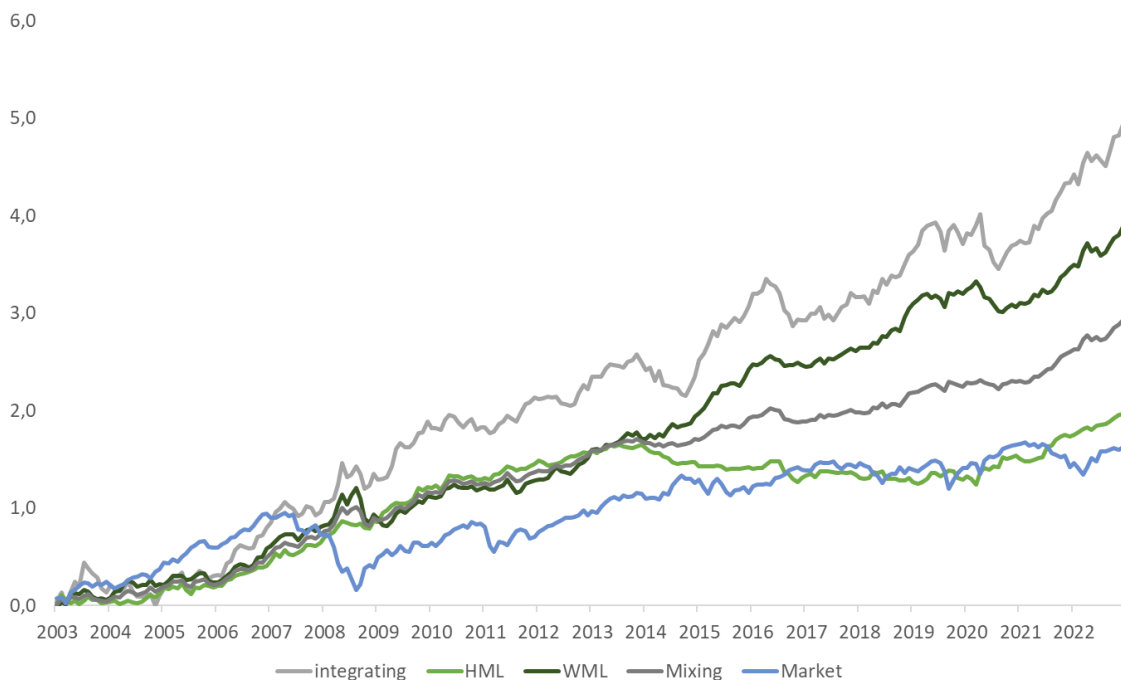


Figure 3. Cumulative returns of the portfolios

Figure 4. presents the cumulative returns for the value and momentum portfolios and combination portfolios. The chart indicates that the strategies exhibit a high degree of independence concerning correlation, and they show a minimal correlation with the market index. Each strategy has been effective in generating significant alpha returns, with statistical significance at the 1% level. Moreover, the chart highlights that while the strategies produce varying returns, they also exhibit distinct risk profiles. The Market index suffered the most significant drawdown during the financial crisis. Additionally, as noted by Daniel et al. (2016) and other literature, the Momentum strategy did not undergo a substantial crash following the financial crisis.

8 Conclusions

This thesis investigates the momentum and value factors in the German stock market. The purpose of this study is to evaluate whether these individual strategies can outperform the market and to determine if a combined strategy can achieve even higher risk-adjusted returns. Additionally, the study aims to explore a more recent approach of integrating the two strategies, requiring both value and momentum signals.

The findings indicate that the momentum anomaly is the more effective of the two factors examined, surpassing the market index in both raw and risk-adjusted returns. This aligns with prior research, which typically identifies momentum as the most effective factor. In contrast, value investing demonstrates lesser efficacy, generating significantly lower returns than the momentum anomaly. Despite this, it still manages to outperform the market in terms of both raw and risk-adjusted returns.

Combining these two strategies significantly enhances the Sharpe ratios compared to individual portfolios, attributable to the reduced volatility in the combined portfolio. Additionally, these strategies perform well in different market phases, making their mix highly effective. In the mixing approach, momentum proves to be highly effective in generating returns, while the value effect contributes to a lowered standard deviation. This combination results in a high Sharpe ratio, making it the best-performing portfolio in terms of risk-adjusted returns. Although the integration portfolio achieves higher overall returns, its heavy concentration in momentum stocks leads to increased standard deviations, thus lowering the Sharpe ratio. The low correlation between the momentum and value strategies enhances the effectiveness of combining investment approaches, providing a diversified and robust strategy for investors.

The study has some limitations that need to be considered. First, it does not account for transaction costs, which, as suggested by Fisher et al. (2016), could significantly impact the returns. Ignoring these costs may limit the applicability of the findings in real-world investing situations, where such expenses could be unavoidable. Furthermore, the CDAX

index includes a relatively small number of stocks compared to other markets and indices. This limitation could result in a high concentration of specific stocks within portfolios, particularly in the integration approach and top-third portfolios. Such concentration risks may skew the results and reduce the generalizability of the study's conclusions.

In conclusion, this study demonstrates that value and momentum strategies yield significant returns, indicating their potential utility in professional asset management. Despite discussion suggesting that the value and momentum anomalies have diminished in global markets, the findings reveal that these strategies remain effective within the German market. For future research, it would be beneficial to incorporate transaction costs to provide a more realistic assessment of the strategies' performance. Additionally, expanding the scope to include stocks from other European economies would enhance the robustness and applicability of the findings, offering a more comprehensive view of the strategies' effectiveness across diverse market conditions. Various interpretations of momentum and value investing could be utilized in portfolio construction. For instance, future research could explore different momentum measures, such as 3-month versus 12-month price changes, or different value metrics.

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