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Master Thesis

The Effect of German Yield Curve Inversion on the German, Dutch, and Swiss Stock Markets

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Table of Contents

1. Introduction

Over the past thirty years, the global financial landscape has been characterized by some of the most turbulent and notable periods, including the dot-com bubble, the 2008 financial crisis, and the COVID-19 pandemic. In the world of investing, where market returns and volatility are of interest to everyone, investors are always curious about what drives the market movements. Economic metrics like GDP growth, inflation rates, and employment figures offer vital clues about economic health and market direction, similarly, shifts in monetary policy, interest rates, and fiscal stimulus measures enacted by central banks and governments can significantly impact asset prices and market sentiment (Asprem, 1989).

Yield curve inversions have been found to be an indicator of an upcoming economic recession (Campbell, 1995; Wright, 2006). This research examines the relationship between the slope of the German yield curve and the stock markets of Germany, the Netherlands, and Switzerland. The slope of the Treasury yield curve, which is the difference between the yield on the long-term bond and the yield on a short-term bond, has been used as an economic indicator showing the state the economy is in, with the inversion of the curve signaling an upcoming recession (Campbell, 1995; Wright, 2006). As yield curve inversion is, thus, found to be a predecessor of an economic recession, authors have studied the effect of this phenomenon on the stock market performance. Fama and French (1989) find a positive association between excess returns on US stocks and corporate bonds and the slope of the US Treasury yield curve. They argue that the yield curve serves as a proxy for discount rate shocks, affecting both stocks and long-term Treasury bonds due to their sensitivity to changes in investors' intertemporal discount rates. Boudoukh et al. (1993) and Ostdiek (1998) demonstrate how ex ante risk premiums on US and global stock portfolios tend to be negative following periods of inverted yield curves. The yield curve or the term structure of interest rates is the relationship between short- and long-term interest rates (Campbell, 1995). These studies mostly studies focus on the effect of US yield curve inversion on stock market performance. This study on the other hand, focuses on the European market, specifically on the German yield curve. This yield curve inverted in January 2023 and has been inverted until writing this paper, May 2024, based on the yields retrieved from Federal Reserve of Economic Data of the Federal Reserve Bank in St. Louis.

A core study within finance revolves around how an asset's expected return is determined by its associated risks (Perold, 2004). This concept has gained traction since the development of the Capital Asset Pricing Model (CAPM). It was developed in the 1960s, and it was the initial comprehensive framework for asset pricing (Perold, 2004). The CAPM has been extended in multiple ways. Fama and French (1992) introduced a model that adds a “value” and a “size” factor in addition to the already existing market factor which improves the explanatory power of the CAPM. Later, Fama and French proposed a five-factor model in (2015), which includes the market, “size”, “value”, “profitability”, and “investment” factors as explanatory variables for average stock returns. The asset pricing models developed by Fama and French have emerged as some of the most widely recognized in finance (Harvey et al., 2016). Empirical evidence suggests that the Fama-French five-factor model effectively captures variations in returns under specific conditions (Cakici, 2015; Cox & Britten 2019). Given the recognition of the Fama-French Three Factor and Five Factor Models, numerous extensions have been introduced (de la O González & Jareño, 2019). These extensions, in addition to the existing variables in the models, include additional factors such as macroeconomic indicators like yield curve factors, nominal interest rates and expected inflation rates or factors related to firm performance, such as momentum (Carhart, 1997; de la O González & Jareño, 2019; Dirkx & Peter, 2020).

This study employs the Fama-French Five Factors Model including Carhart’s Momentum Factor (FF5M) to investigate the relationship between the yield spread and the stock market performance. The FF5M is expanded by adding a yield curve factor. Three variations of the yield curve factor are used to capture various effects the yield curve might have on the stock markets. This paper aims to investigate the spillover effect of Germany’s yield curve on smaller economies’ stock markets, e.g., the Netherlands and Switzerland. Using the three country’s main stock indices data from November 1990 to December 2023, this relationship for these three industrialized countries is examined. The German stock market is represented by the DAX, MDAX, and SDAX indices, which respectively consist of large-cap, mid-cap, and small-cap stocks. Similarly, the Dutch market is reflected through the AEX, AMX, and ASCX indices. Finally, the Swiss market is mirrored by the SMIM, SMI, and SMCI indices, each catering to different segments of the market based on market capitalization.

By employing this method, this paper aims to answer the research question of this paper which is formulated as follows:

How does the German yield curve relate to the German, Dutch, and Swiss stock market performance, considering normal and inverted yield curve conditions?

To answer this question, three hypotheses are tested in this research.

Fama and French (1989) find that the slope of the US yield curve is positively related to the excess returns. Moreover, McCown (2001) finds that inversion of the yield curve inversion, or a negative slope of the German yield curve, negatively affects stock market performance in Germany, the Netherlands, and Switzerland. This results in the first hypothesis:

H.1 *The German yield curve has a positive relationship with the excess returns of the German, Dutch, and Swiss stock market.*

Killins and Chen (2022) find lagged effects of the yield curve changes on the stock market performance. They argue that it may be challenging for investors to accurately absorb the impact of information stored in changes in the yield curve. Hong and Stein (1999) and Hong et al. (2007) support this and introduce the gradual information diffusion theory. This theory suggests that security prices tend to underreact in the short term when information diffuses gradually. Hence, the second hypothesis becomes:

H.2 *The German yield curve has a lagged effect on the German, Dutch, and Swiss stock market returns.*

Killins and Chen (2022) also argue that changes in the yield curve changes affect stock market returns asymmetrically. They show that changes in the US yield curve indeed affect the equity returns of US insurance companies differently during inversions. Therefore, the third hypothesis is tested to get a better understanding of the impact of changes in the yield curve slope during periods of inversions:

H.3 *The German yield spread has asymmetric effects on the German, Dutch, and Swiss stock market returns.*

The analysis reveals that the German yield curve has a significant positive relationship with stock market performance in Germany and the Netherlands, particularly for the DAX, AEX, and ASCX indices. However, the impact on Swiss indices is insignificant. Lagged models show mixed results. The inclusion of an interaction term indicates limited asymmetric effects of yield curve inversions. Overall, the findings suggest that the yield curve's impact varies across countries and time frames.

Although the main aim of this research is to get a better understanding of the relation between the German yield curve and the German, Dutch, and Swiss stock market performance, this study also briefly examines if the proposed expansions of the FF5M models improve the asset pricing models. That way, it follows Schuerman and Stiroh (2006) who expand capital asset pricing models. Yet, the main goal of these authors is not to improve existing capital asset pricing models, but to assess relationships between the stock performance and the macroeconomic variables. Therefore, the aim of this study is to explore a practical example, showing how the changes in the yield spread affect the market returns.

The results of this research may provide a better understating of the drivers of market returns of Germany, Switzerland and the Netherlands, and a better insight into the performance of the extended FF5M model. Estrella and Mishkin (1996) argue that these findings may be of interest to anyone partaking in the financial markets, from investors to policy makers. They also argue that investors should learn how the yield curve can affect their portfolios, and policy makers should understand the implications of their monetary policy changes.

The thesis is structured as follows: in the following section, Section 2, the literature review is presented. In Section 3 the methodology is presented, detailing the dataset and describing the method used. This section also explores the data by performing a relatively straightforward test similar to McCown (2001) who found evidence for spillover effects using a two-sample mean z-test. In Section 4, the results from the models are presented. The last two sections, Sections 5 and 6, cover the results and conclusion. Here, the findings are connected to the relevant works from Section 2 and are once again summarized.

2. Literature Review

This chapter delves into the yield curve, beginning with foundational definitions of fixed income securities and the concept of yield to maturity. It then explores the plotting and implications of the yield curve and yield spread. The discussion extends to factors influencing the yield curve and its predictive power regarding future economic activity. Additionally, the chapter investigates the yield curve's impact on stock market returns and international financial markets. Finally, the Capital Asset Pricing Model and Fama-French models are introduced, with a discussion on their extensions and the incorporation of yield curve factors to assess the yield curve's impact on stock market performance.

2.1 Understanding The Yield Curve

Fixed income securities (FI securities), such as bonds and Treasury notes, are defined as payments made to investors that are fully specified in advance (Asgharian, 2024). These securities promise a stream of future cash flows in advance to the investor. FI securities can be categorized as either short-term or long-term. Short-term FI securities have a maturity of up to one year, whereas long-term FI securities have a maturity of more than one year (Asgharian, 2024; Campbell, 1995).

Equation 1 illustrates how the price of a FI security is related to the yield to maturity (Asgharian, 2024). Here, P_{nt} is the price of the FI security at time *t* with *n* periods to maturity. CF_{t+i} represents the cash flows that the FI security promises at different times. Y_{nt} is the yield to maturity, which is the single discount rate that equates the present value of the bond's payments at different times to its price (Asgharian, 2024). The equation is as follows:

$$P_{nt} = \sum_{i=1}^{n} \frac{CF_{t+i}}{(1 + Y_{nt})^i} \qquad (1)$$

Equation 1 essentially calculates the current price of the bond by discounting each future cash flow back to its present value using the yield to maturity as the discount rate. The equation clarifies that the yield to maturity can be calculated for securities with various maturities. The different yields for each respective maturity are used to plot the yield curve. Figure 1 shows that, normally, the yield curve slopes upward. In other words, FI securities with longer (shorter) maturities have higher (lower) yields to maturities. Yield curves can, however, also be inverted as shown in the graph on the right side of figure 1. In this case, FI securities with shorter (longer) maturities have higher (lower) yields to maturities.

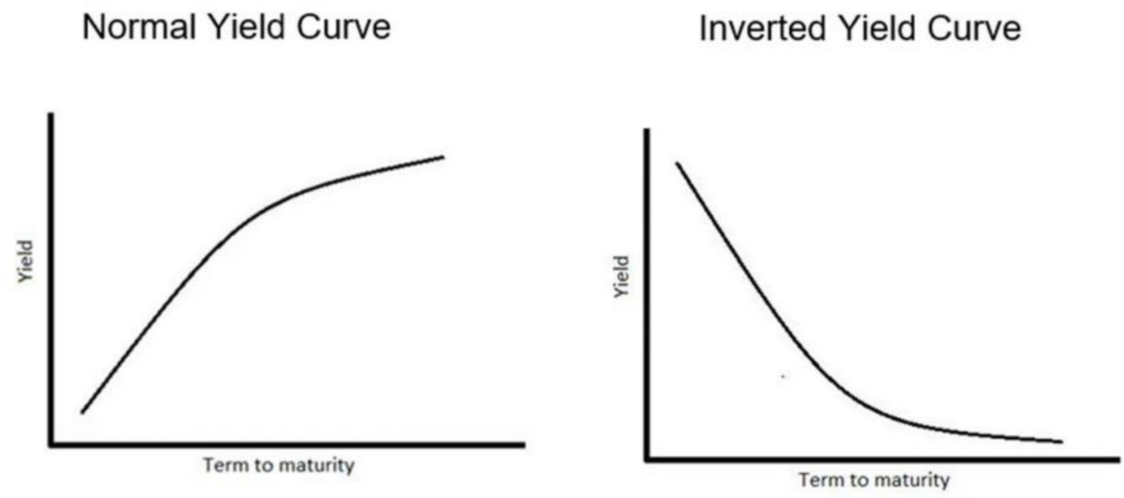

Figure 1: The normal yield curve (left) and inverted yield curve (right) graphically illustrated (Shah, 2020). For a normal yield curve, the yield to maturity is higher for securities with a longer time to maturity than for securities with a shorter time to maturity. This is indicated by the upward slope of the yield curve which indicates a positive yield spread. For an inverted yield curve, the yield to maturity is lower for securities with a longer time to maturity than for securities with a shorter time to maturity. This is indicated by the downward slope of the yield curve which indicates a negative yield spread.

The yield to maturity for a long-term FI security is the long-term yield (Y_{nt}), and the yield to maturity for a short-term FI security is the short-term yield (Y_{1t}). The difference between these yields results in the yield spread (S_{nt}) as shown by equation 2 (Asgharian, 2024). The yield spread is used as a measure of the slope of the yield curve. Yield spreads are, thus, positive in the normal case and negative when the yield curve is inverted (Campbell, 1995).

$$S_{nt} = Y_{nt} - Y_{1t} \tag{2}$$

Fama and Bliss (1987) explain that the yield spread, in other words the expected returns of a term structure, are usually interpreted as rewards for risk. They argue that when changes in the expected returns across different time horizons are observed, it suggests that the ranking of risks associated with those time horizons is also changing.

Asgharian (2024) defines the forward rate as an interest rate on a transaction that will take place in the future. He explains that the forward rate equals the anticipated future interest rate plus an additional risk premium (*RP*) as shown in equation 3. F_{it} is the forward rate where *i* represents the period of the agreement after year *t* when the agreement is made:

$$F_{it} = E_t\left[R_{n,t+i}\right] + RP \tag{3}$$

Economists have extensively explored the relationship between forward interest rates, derived from current rates on debts with various maturities, and market participants' expectations of future interest rates (Hicks, 1939; Lutz, 1940). Hicks (1939) indicates that implied forward rates may deviate from expected future rates due to factors such as a liquidity premium. Additionally, Stiglitz (1970) investigates how market participants' risk aversion could contribute to such a premium. He states that while the premium could theoretically be positive or negative, the typical upward slope of the yield curve suggests a positive premium, which tends to increase with the debt's maturity period. Furthermore, it has been proposed that the premium for a specific maturity might fluctuate with real economic activity (Kessel, 1971), and that relative quantities of outside debt supply may also influence the premium (Culbertson, 1957).

2.1.1 Causes of a Yield Curve Inversion

Current monetary policy significantly affects the yield curve spread and subsequently impacts real economic activity over the next several quarters (Estrella & Mishkin, 1996). Cooper et al. (2020) observe that when the central bank temporarily raises short-term interest rates, long-term rates tend to increase less proportionately. Estrella & Mishkin (1995) argue that central banks can raise short-term interest rates by contracting credit supply which results in rate hikes, whereas the long-term rates are more responsive to shifts in expected inflation and real ex ante long-term rate. They also discuss that if the tightening measures are perceived as credible and effective, the reduction in long-term inflation expectations tends to counterbalance the tightening effect on short-term rates caused by credit contraction. As a result, long-term rates generally rise less than short-term rates (and could potentially decline), leading to a narrowing of the spread between long- and short-term rates. This phenomenon is often referred to as a flattening of the yield curve because long-term rates reflect expectations that future short-term rates will eventually decrease. Consequently, tighter monetary policy can lead to an inverted yield curve, potentially indicating weaker economic activity in the future (Cooper et al., 2020). However, it is important to note that while monetary policy tightening can contribute to yield curve inversion, it may not be the sole or primary cause of a recession. For instance, historical data from the Federal Reserve Board staff before recent recessions indicates that efforts to slow economic growth were aimed at achieving a sustainable pace, rather than intentionally causing a recession (Cooper et al., 2020). Nevertheless, misjudgments regarding the impact of policy tightening or unforeseen adverse factors could exacerbate the situation (Estrella & Mishkin, 1995; Cooper et al., 2020).

Cooper et al. (2020) also argue that expectations about future economic activity and associated predictions about future monetary policy influence movements in the long-term rates. They explain that as investors anticipate an economic slowdown, the investors tend to invest in long-term Treasury bonds. This increased demand for bonds results in higher prices for these securities. Hence, the yields of these securities decrease.

2.1.2 Predictive Power of the Yield Curve

Estrella and Mishkin (1995) show that the yield spread can offer valuable insights into market expectations regarding future real economic activity and inflation. This is confirmed by Cooper et al. (2020) who describe the yield spread as a measure that captures information about the investors' market expectations and monetary policy. They stress that the latter is closely linked to the current phase of the business cycle and can provide insights into the probability of an economic downturn. It is shown that the yield spread has a negative relationship with the likelihood of an economic recession (Estrella & Hardouvelis, 1991; Estrella and Mishkin, 1996; Estrella & Mishkin, 1998). Wright (2006) also states that the yield spread has a positive relationship between with real GDP growth in the following periods.

Mishkin (1990a, 1990b) explains that the yield curve has predictive ability as it holds information about the expectations about future monetary policy. As explained before, the yield curve spread corresponds to a forward interest rate. Mishkin (1990a, 1990b) explains that this rate consists of two components: the expected real rate and expected inflation. Where the expected real rate is associated with future monetary policy. Furthermore, the expected inflation has a positive association with economic activity and may, therefore, hold information about future economic growth (Estrella & Mishkin, 1995; Estrella & Mishkin, 1996).

Overall, the predictive power of the yield curve for future economic activity can be attributed to its ability to aggregate information from various sources and reflect investors' expectations about the economy's future prospects (Cooper et al., 2020). Unlike other financial indicators, such as broad stock market indices, the yield curve provides additional insights into investors' risk perceptions and incorporates information about the monetary policy stance, making it a valuable tool for assessing the likelihood of future downturns (Cooper et al., 2020).

Specifically, Estrella and Mishkin (1995) find that the yield curve spread is a good indicator of future economic activity and the probability of a recession with a lead time of one to two years, depending on the measure of economic activity. For example, the yield curve spread is a good predictor of future inflation with a lead of generally three to five years (Estrella & Mishkin, 1995). Moreover, they conclude that the level of ex ante probability of an impending recession is much higher approximately a year before the downturn and should be seen as a clear sign of real slowdown. They show that the predicted probability of a recession in good times is very close to zero, so any sort of increase can be interpreted as a sign of an anticipated recession.

Moreover, Mishkin (1990a, 1990b, 1991) and Jorion and Mishkin (1991) research the predictive power of yield curve spreads in forecasting changes in inflation. The results indicate that the predictive power in the short term, so within six months, is almost nonexistent. The prediction power goes up past nine or twelve months. Estrella and Mishkin (1995) extend this to longer horizons, namely by using the 10-year minus a 3-month interest rate. The results match those of Jorion and Mishkin (1991) as the predictive accuracy is higher at longer horizons.

2.1.3 The Effect of the Yield Curve on the Stock Market

Fama and French (1989) conclude that the excess returns are positively associated with the yield curve spreads. The authors study a period from 1927 to 1987 and argue that the yield curve spread accounts for a term premium in the excess returns of long-term securities. Specifically, this term premium is said to be based on the maturity of a security. The findings of Fama and French (1989) correspond with the earlier statement of Cooper et al. (2020) who state that yield curves flatten as investors anticipate economic downturn.

Schuermann and Stiroh (2006) study US bank holding companies from 1997 to 2005. They find, by adding a yield curve factor to asset pricing model, that negative changes in the yield curve, or flattening of the yield curve, are associated with negative stock returns. Other authors that use similar methods are Killins and Chen (2022). These authors find a negative relationship between the yield curve and the returns of US and Canadian insurance companies, although statistically significance is lacking for the Canadian companies. Killins et al. (2021) find that Canadian banks equity returns have a positive relationship with both unlagged and 1-month lagged yield curve spreads. These authors studied a period from January 1997 to August 2018.

Fama and French (2019) find no evidence that yield curve inversion predicts negative stock returns within one, two, three, and five years. However, Quin et al. (2020) find that the stock markets incorporate the information from yield curve inversion almost instantly similar to Faria & Verona (2020). Quinn et al. (2020) explain that this conclusion shows the investors' anticipation of downturns in the market based on the yield curve and this anticipation likely causes negative returns on the stock market. Boudoukh et al. (1993), McCown (1999), Killins et al. (2021) and Killins and Chen (2022) find similar results but show that there may be some lag between the inversion and the decrease in excess return. This indicates that investors struggle with absorbing the information provided by changes in the yield curve. Hong and Stein (1999) and Hong et al. (2007) explain such phenomenon using the gradual information diffusion theory which suggests that when information diffuses gradually, stock prices tend to underreact to this new information.

Boudoukh et al. (1993) not only show that the US yield curve has predictive power for the US stock market, but also that the inverted US yield curves are followed by negative risk premiums for world stock portfolios. This shows that the US yield curve has predictive for foreign stock markets as well. Dahlquist and Harvey (2001) confirm these findings. McCown (2001) concludes that the US and the German yield curve inversions are followed by negative risk premiums in foreign, smaller economies. Resnick et al. (2002) also show that the US yield spread is more useful than the domestic yield spread to time the market. To conclude, the yield spreads of large economies are found to be more useful to forecast the markets than the domestic yield spreads which indicates a spillover effect.

To explain why these spillover effects exist, it is fundamental to understand that international economies are intertwined through trade and investment (Lin et al. 1994). Moreover, Neely (2001) explains that international economies tend to share macroeconomic shocks and that central banks react to these shocks in a similar manner. Specifically, he states that the monetary changes in large economies tend to be followed by similar adjustments in smaller economies engaged in trading activities with them.

The next part introduces asset pricing models, Fama-French models, and their extensions that add a yield curve factor.

2.2 The Capital Asset Pricing Model

The CAPM was introduced by Sharpe (1964) and Lintner (1965) and is based on the tradeoff between risk and reward (Elbannan, 2015). The model is built on two main assumptions. Firstly, it is assumed that borrowing and lending is possible at the risk-free rate. Secondly, investors have homogeneous expectations, meaning they agree on how future asset returns are expected to be distributed.

These two assumptions are added onto the market portfolio model from Markowitz (1959). The market portfolio model operates under the assumption that investors, being riskaverse, aim to strike a balance between risk and return within a single period. Their investment choices are made as such that expected returns are maximized for a specified level of variance. Hence, this model is a mean-variance model (Elbannan, 2015). Capital Market theory describes this assumption as the phenomenon of investors taking a position on the efficient frontier to maximize their utility. The exact location on the efficient frontier depends on their specified level of risk which can be derived from the respective utility function. Additionally, the model assumes that investors have the flexibility to adjust their holdings by buying or selling portions of securities or portfolios. Furthermore, asset transactions are without taxes and transaction fees. Next, the model assumes no fluctuations in inflation or interest rates. Finally, the capital markets are assumed to be in a state of equilibrium where investors cannot influence the prices (Reilly & Brown, 2003).

Figure 2 depicts the investment opportunities and shows how CAPM works (Fama & French, 2004). The horizontal axis depicts the levels of risk measured as the levels of variance of portfolio return. The vertical axis depicts the expected portfolio return. The minimum variance frontier is displayed by curve *abc* and shows the possible combinations of expected return and risk. An investor at points *a* needs to accept a high level of risk if this investor prefers a high expected return. An investor at point *T* has a more moderate level of expected return which goes with lower volatility. Without borrowing and lending at the risk-free rate, only the portfolios above *b* are mean-variance-efficient as these portfolios carry the highest expected return for the respective levels of risk (Fama & French, 2004). However, if borrowing and lending at the risk-free rate is possible, the curved lines become straight lines. At this point, investor can invest all the available funds into riskless assets which results in R_f; zero variance and the expected return equals the risk-free rate. A second option for the investor is to make combinations between risk-free lending and investing in risky portfolio *g*. A third option is to borrow at the risk-free rate and invest this as well in portfolio *g*; these points are to the right of point *g* in the graph.

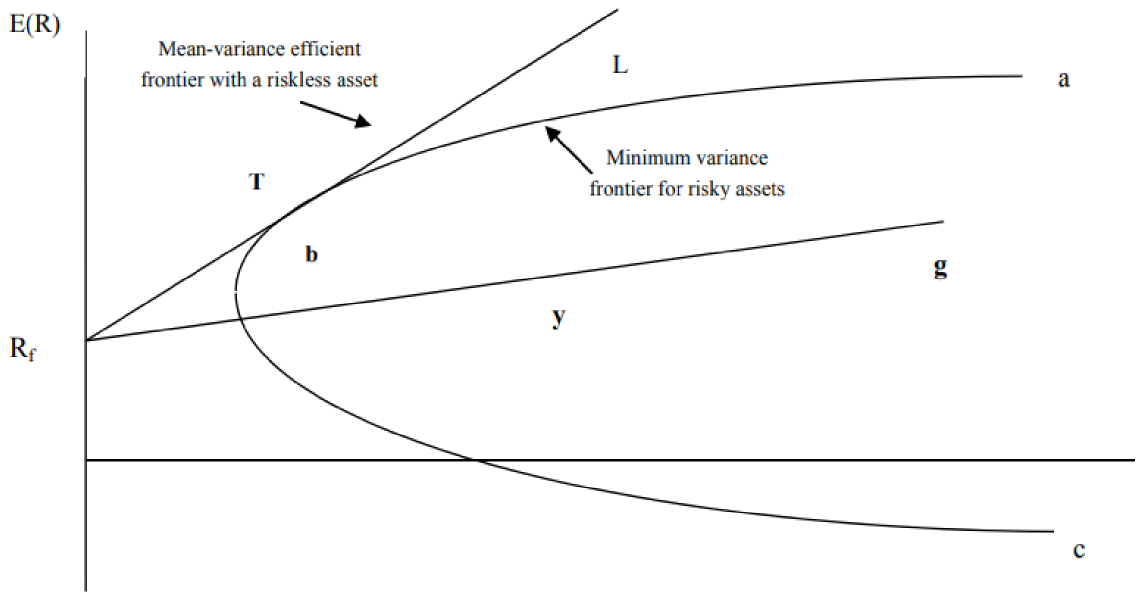

Figure 2: Graphic representation of the investment opportunities with expected return on the y-axis and risk on the horizontal axis (Fama & French, 2004).

Finally, the mean-variance-efficient portfolios are depicted by line *L* which is a straight line starting in R_f tangent to point *T*. This line shows "… that all efficient portfolios are combinations of the risk-free asset … and a single risky tangency portfolio, *T*." (Fama, & French, 2004, p. 28). Thus, the opportunity set for each investor is the same which is the value-weighted market portfolio. Using risk-free borrowing and lending, investors can create a value-weighted portfolio according to their risk appetite, known as Tobin's (1958) separation theorem. CAPM implies that the market portfolio lies on the minimum variance frontier. Hence, for *N* risky assets:

$$E(R_i) = E(R_{ZM}) + [E(R_M) - E(R_{ZM})]\beta_{iM}, i = 1, \dots, N \qquad (4)$$

Where $E(R_i)$ is the expected return of asset *i*, $E(R_{ZM})$ represents the expected return on assets with market betas equal to zero, $E(R_M)$ is the expected market return, and β_{iM} is the market beta of asset *i* and can be calculated by dividing the covariance of the return of asset *i* by the market return's variance (Elbannan, 2015; Fama, & French, 2004). $E(R_{ZM})$ is equal to the risk-free rate according to the Sharpe-Lintner model; if an asset's return is not correlated to the return of the market, the asset has a market beta of zero (Fama, & French, 2004). In other words, such an asset is riskless and, therefore, $E(R_{ZM})$ is set to R_f:

$$E(R_i) = R_f + [E(R_M) - R_f)]\,\beta_{iM}, i = 1, \dots, N \qquad (5)$$

The next section discusses how Fama and French expanded this model to improve the asset pricing model.

2.3 Fama-French Three Factor Model

The Capital Asset Pricing Model (CAPM) considers only one risk factor, namely the market (Perold, 2004). Numerous empirical tests have been conducted on the CAPM, and they suggested that market betas sufficiently explained the expected returns of assets. However, later empirical tests indicated that a significant portion of the variation in expected returns could not be explained by market beta alone. Other variables were identified as able to explain the cross-section of average returns. These variables included size (market value of equity), leverage, earnings/price, and book-to-market equity (the ratio of book value of equity to market value of equity) (Fama & French, 1993; Fama & French, 2004).

Contradictions to the CAPM included findings that high leverage was associated with returns that were too high relative to an asset's beta, and that stocks with high book-to-market equity had high average returns not captured by their betas (Fama & French, 2004). Additionally, Fama & French (1992) find that beta had little explanatory power for average returns, whether used alone or with other variables (Fama & French, 1993).

When examining these variables alongside market beta, Fama and French (1992) discover that they enhance the explanation of expected stock returns beyond what was provided by market beta alone (Fama & French, 2004). Moreover, Fama and French (1992) find that size and book-to-market equity seemed to consider the roles of leverage and earnings/price in explaining the cross-section of average returns (Fama & French, 1993). The higher returns on small stocks and high book-to-market stocks were attributed to unidentified state variables that caused undiversifiable risks in returns, which were not captured by market return and were priced separately from market betas (Fama & French, 2004).

Based on their findings and empirical testing, Fama and French (1993, 1996) proposed a new model for explaining expected returns, the Fama-French Three Factor Model (Fama & French, 2004). The model is as follows:

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \varepsilon_{it} \qquad (6)$$

Fama and French (1993) Three Factor Model aims at estimating the excess return on a stock using three factors: Market excess return ($R_{mt} - R_{ft}$), Small Minus Big (SMB_t), High Minus Low (HML_t). $R_{mt} - R_{ft}$ represents the market risk and is defined as the excess return of a value-weighted market portfolio over the risk-free rate. SMB_t represents the difference in returns between diversified portfolios of small stocks and large stocks, capturing the size factor which reflects market capitalization. To calculate SMB_t, the average return of a diversified portfolio containing big stocks is subtracted from the average return of a diversified portfolio containing small stocks. HML_t represents the value factor, assessing the book-to-market (B/M) value and captures the difference in returns between diversified portfolios of high and low B/M stocks. It is estimated by averaging the returns of portfolios containing companies with high B/M ratios and subtracting the average returns of portfolios containing companies with low B/M ratios.

2.4 Fama-French Five Factor Model and Carhart's Momentum Factor (FF5M)

The Three Factor Fama-French Model is expanded with two additional factors, namely, Robust minus Weak (RMW_t) and Conservative minus Aggressive (CMA_t) (Fama & French, 2004).

RMW_t, the profitability factor, is estimated by subtracting the interest expense from operating profit. Similar to SMB_t and HML_t, the average return of low operating (weak) profit portfolios is subtracted from the average return of high operating (robust) profit portfolios. The last factor in FF5 is CMA_t, the investment factor. CMA_t assesses the ratio of growth in total assets in the previous year divided by the total assets in the previous year. It reflects the difference in returns between diversified portfolios of stocks categorized as either conservative (low investment) or aggressive (high investment) firms.

In addition to FF5, the Momentum factor (WML_t) measures the difference in portfolio returns based on high momentum stocks (winners) and portfolio based on low momentum stocks (losers) (Carhartt, 1997). Carhartt (1997) argues that stocks' trend of overperforming (underperforming) the market tends to continue. Combining the factors above results in the model illustrated by equation 7.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 WML_t + \varepsilon_{it} \tag{7}$$

2.5 Expansions of FF5M

As previously mentioned, existing literature introduces a multitude of extensions of the Fama-French Three Factor and Five Factor Models which include additional macroeconomic variables. (de la O Gonzáles & Jareño, 2019).

Killins et al. (2021) and Killins and Chen (2022) expand the Five Factor Model with various measures of the yield curve under different assumptions as shown by equation 8 to 12.

They base their models on the models from Baur and Todovora (2018) who expand a Fama-French factor model with the changes of the oil price to find the effect of such changes on the stock performance of the automotive sector. The benchmark model used is displayed in equation 8. They add the variable YC_t which represents the changes in yield spread.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 YC_t + \varepsilon_{it} \tag{8}$$

Using this model, Killins et al. (2021) find a positive relationship between the changes in yield curve and excess bank-stock returns. However, Killins and Chen (2022) find a negative relationship between the changes in yield curve and excess insurance-stock returns. They argue that this negative relationship may exist because insurers may have higher reserve requirements because of increased discounts in asset valuation which decreases business expansion.

Next, the authors test for potential asymmetric effects of the yield curve effects on the excess returns. Therefore, they expand their benchmark model with an interaction term (YC_tD_t) which is shown in equation 9. The authors set the dummy variable to 1 if it is above a certain threshold and to 0, if otherwise. An asymmetric effect is found if the coefficient of the interaction term is significantly different from 0. Killins et al. (2021) and Killins and Chen (2022) find that yield spread changes above the threshold have a positive effect on the excess returns.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 YC_t + \beta_7 YC_t D_t + \varepsilon_{it} \tag{9}$$

To improve the understanding of the asymmetric impacts of the yield curve on returns, the yield curve series is split into two. The first includes only the yield curve increases, YC^+, and another includes only the yield curve decreases, YC^-. The authors reason that this condition is to conclude whether economic agents respond differently to positive and negative movements in the slope of the yield curve. This alternative model is specified in equation 10.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 YC^+ + \beta_7 YC^- + \varepsilon_{it} \tag{10}$$

Killins et al. (2021) find that decreases in the yield spread are associated with decreases of the excess returns, whereas the increases have a positive effect on the excess returns. Killins and Chen (2022) do not find statistically significant results for the effect of increases of the yield curve spread on excess returns. However, they find that decreases of the yield spread are associated with decreases of the excess returns of American insurance stocks.

Lastly, the authors test for a 1-month lagged effect of changes in the yield spread, YC_{t-1}, on the returns using equation 11. Killins et al. (2021) find positive statistically significant associations between the lagged changes in the yield spread and the excess returns. Killins and Chen (2022) also find statistically significant results. Similar to their results using the unlagged yield curve changes, the association between the change in yield spread is negatively related to excess return.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 YC_{t-1} + \varepsilon_{it} \tag{11}$$

Additional research has identified other significant determinants of returns in addition to the Fama-French Three Factor Model. For instance, studies by Ang et al. (2006) and Adrian and Rosenberg (2006) demonstrate that overall market volatility is a priced factor. Rosenberg and Schuermann (2006) have also found variations in factor loadings across different credit spectrums. Moreover, there is growing evidence suggesting that liquidity risk commands a premium, as indicated by the work of Amihud (2002) and Pastor and Stambaugh (2003), who show that investors demand higher returns for holding illiquid stocks. Consequently, Schuermann and Stiroh (2006) introduce a comprehensive model that integrates the Fama-French Three Factor model with six additional risk factors, resulting in a Nine Factor model:

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 VOL_t + \beta_5 \Delta YIELD_t + \beta_6 \Delta TERM_t + \beta_7 \Delta Aa_t + \beta_8 \Delta Baa_t + \beta_9 \Delta CP_t + \varepsilon_{it} \tag{12}$$

In equation 12, VOL_t represents the one-period overall market volatility, $\Delta YIELD_t$ stands for the one-period change in the risk-free rate, $\Delta TERM_t$ represents the one-period change in the slope of the term structure, ΔAa_t is the change in the option adjusted credit spread for Moody's Aa-rated corporate bonds, ΔBaa_t, therefore, signifies the one-period change in the option-adjusted credit spreads for Baa-rated corporate bonds, lastly, ΔCP_t is the change in the 90-day financial commercial paper spread above the maturity matched Treasury rate.

2.5.1 Limitations of the Expanded Models

Some studies demonstrate that certain Fama-French factors already capture the information held by a yield curve factor holds. Petkova (2006) shows that the Fama-French factors proxy for innovations in certain macroeconomic variables. Specifically, Petkova indicates that when dividend yield, yield curve spread, default risk, and the risk-free rate are included in an asset pricing model, the Fama-French factors lose their statistical significance. Leite et al. (2020) support this finding and find that the shocks in these macroeconomic variables proxy for HML and SMB. There is, thus, no consensus within literature regarding the impact of extending the Fama-French factor model with these macroeconomic variables.

2.6 The Overview of German, Dutch, and Swiss Economies

It has been explained that changes in the yield curve may affect the markets in other countries. This study focuses on the effects of changes in the German yield curve to the German, Dutch, and Swiss markets. To provide more context, the following section provides a brief overview of these countries’ economies.

2.6.1 Germany

Germany is a highly developed country with the third largest GDP in the world and the largest in Europe (IMF, 2024). Known for its robust industrial base, Germany is a global leader in automotive manufacturing, machinery, and chemical products, reflecting its strong secondary sector (Destatis, 2024c). In 2022, industry, including construction, accounted for approximately 24% of GDP, while services made up about 75%, and agriculture around 1% (Destatis, 2024a).

Germany's economic success is largely attributed to its export-oriented economy, with exports making up around 51% of its GDP and imports comprising of around 49% of its GDP (World Bank, 2024). It is the third-largest exporter and importer globally, emphasizing its integration into the world economy (BMWK, 2019). Germany's commitment to international cooperation is reflected in its membership in key organizations such as the European Union (EU), United Nations (UN), G7, G20, NATO and many more. (Federal Foreign Office, 2024).

2.6.2 The Netherlands

The Netherlands boasts a highly developed economy with one of the highest GDP per capita in the world, ranking sixth among OECD countries in 2022 (OECD, 2024). The Netherlands is the second largest importer and exporter of goods in the European Union, just after Germany, and plays a major role in distributing goods from outside the European Union (EU) to other EU countries (CBS, 2024). Dutch economy is diversified, with services accounting for about 81% of GDP, industry around 17%, and agriculture approximately 2% in 2022 (Destatis, 2024a).

The Netherlands' economy is highly open, with exports making up almost 94% of its GDP, and imports around 83% of its GDP (World Bank, 2024). The Netherlands is one of the top global recipients and sources of foreign direct investment (FDI), and it stands out as a major historical recipient of direct investment from the United States (US Department of State, 2023a). Furthermore, it is a member of the EU, UN, NATO, World Trade Organization (WTO), Organization for Economic Co-operation and Development (OECD) and many more (Government of the Netherlands, 2024).

2.6.3 Switzerland

Switzerland is a prosperous and highly developed country, with one of the highest GDP per capita, ranking third among OECD countries in 2022 (OECD, 2024). Known for its strong financial sector, high-tech industries, and pharmaceuticals, Switzerland's economy is characterized by a significant services sector, which accounted for about 74% of GDP in 2022, while industry represented 21%, and agriculture less than 1% (Destatis, 2024b; US Department of State 2023b).

Switzerland's economy is exceptionally open, with exports comprising of around 77% of GDP and imports around 63% of GDP (World Bank, 2022). Switzerland is a major destination for FDI and also a significant investor abroad, Switzerland has attracted substantial investments in key sectors such as information technology, precision engineering, scientific instruments, pharmaceuticals, medical technology, and machine building (US Department of State 2023b). The country participates in numerous international organizations, including the UN, International Monetary Fund (IMF), Council of Europe, NATO, OECD and many more (FDFA, 2024). Although not an EU member, Switzerland has numerous bilateral agreements with the EU, facilitating extensive trade and economic cooperation (FDFA, 2024).

3. Data and Methodology

The following chapter describes the data used in this research. To retrieve some initial insights from the data about the relationship between yield curve inversion and excess returns, a two-sample Z-test is performed following McCown (2001). Lastly, the methodology is discussed.

3.1 Data

The period studied in this research is November 1990 to December 2023 and the data for all variables are retrieved in monthly period. The long-term yield is defined as the yield on 10-year bonds and the short-term yield is defined as the yield on 3-month bonds, following other authors (Quinn et al., 2022; Schuermann & Stiroh, 2006; Killins et al., 2021; Killins & Chen, 2022). This data was retrieved from the FRED, the Federal Reserve of Economic Data of the Federal Reserve Bank in St. Louis. This research tries to find whether and, if so, how the German yield curve affects the stock markets in other countries, specifically The Netherlands and Switzerland. For all three countries, the price data is retrieved from Eikon databases for the large cap, mid-cap, and small cap equity indices. For Germany, the large, mid, and small cap indices taken are DAX, MDAX, and SDAX, respectively. For The Netherlands, these indices are AEX, AMX, and ASCX, respectively. Finally, the large, mid, and small cap indices are SMI, SMIM, and SMCI, respectively, for Switzerland. Finally, the excess market return, risk-free rate, Fama & French factors, and the momentum factor at European level are retrieved from French's website. As aforementioned, the Fama-French factors consist of SMB, HML, RMW, and CMA. Following McCown (2001), the index returns are denominated in local currencies. As such, this research takes the position of an investor that hedges all foreign exchange risk.

The data is summarized in Table 1. The table shows summary statistics of the FF5 factors including the momentum factor, the equity index returns, and the German and U.S. yields and spreads. The average monthly returns for the equity indices range from 0.2551% for SDXK to 0.4296% for MDAX. For both US and Germany, the yield curve spreads are calculated by subtracting the 3-month yield from the 10-year yield. The average German spread, 0.7975%, is notably lower than the average of US spread, 1.3047%, respectively. Although the averages of the spreads differ to some extent, their standard deviations are relatively close with approximately 1.11% for the German spread and 1.28% for the US spread, respectively. ΔUS Spread and YC show the month-to-month difference in yield curve spread for U.S. and Germany, respectively.

Table 1: Summary statistics for the period 1990.11 - 2023.12. The data is in monthly format and all the statistics are in percentages given the nature of the variables.

	mean (%)	min (%)	25%	50%	75%	max (%)	std
Mkt-RF	0.5304	-22.0200	-2.4600	0.7750	3.8150	16.6200	4.9493
SMB	0.0320	-7.3300	-1.1675	0.1150	1.3750	8.8300	2.1027
HML	0.2853	-11.3000	-1.1375	0.3250	1.5000	12.0900	2.6358
RMW	0.3625	-5.4000	-0.5850	0.4450	1.3650	6.4000	1.6186
CMA	0.1212	-7.3000	-0.7575	0.0200	0.9075	8.7700	1.8236
RF	0.2030	0.0000	0.0100	0.1700	0.3900	0.6000	0.1775
WML	0.8372	-26.0900	-0.6825	1.0850	2.6300	13.6500	3.8936
DAX excess return	0.4146	-29.4727	-2.7106	0.8230	3.9571	19.2738	5.8631
SDXK excess return	0.2551	-23.3918	-2.3227	0.6906	3.2403	17.0485	5.1500
MDAX excess return	0.4296	-23.5118	-2.3129	0.9061	3.9693	22.8867	5.2996
AEX excess return	0.3021	-22.7616	-2.4002	0.9413	3.3890	14.4289	5.2714
ASCX excess return	0.2640	-22.3173	-2.2875	0.7962	3.6064	14.7834	5.2543
AMX excess return	0.2608	-27.5538	-2.3818	0.6289	4.0844	16.3512	5.7072
SMCI excess return	0.3357	-24.1848	-1.7682	0.8615	3.4420	13.3338	4.9558
SMIM excess return	0.3288	-20.1899	-1.9157	0.7567	2.8874	12.2941	4.1650
SMI excess return	0.3148	-21.4211	-1.9610	0.8154	2.8997	12.5350	4.2519
Yield US 3-month	2.8365	0.0900	0.5250	2.4850	5.2550	8.0300	2.2375
Yield US 10-year	4.1412	0.6200	2.5225	4.0500	5.7025	8.3900	1.8930
US Spread	1.3047	-1.5800	0.2775	1.3250	2.4025	3.5700	1.2778
∆US Spread	-0.0049	-1.0000	-0.1600	-0.0100	0.1200	1.6800	0.2635
Yield German 3-month	3.4121	-0.6491	1.2717	3.6668	5.1521	8.9275	2.5156
Yield German 10-year	2.6146	-0.5820	0.2049	2.4285	3.9383	9.8800	2.6784
German Spread	0.7975	-1.8475	0.1170	0.7618	1.5576	3.1689	1.1112
YC	-0.0045	-0.6389	-0.1190	-0.0201	0.1097	0.8592	0.1947

3.2 Initial Exploration of Relationship between Yield Curve and Excess Returns

As a first attempt to assess whether the German yield curve affects the equity markets in Germany, The Netherlands, and Switzerland, a two-sample Z-test is performed following McCown (2001). This test is used to assess whether the two conditional means are statistically different. For each index, the dataset is divided into two samples conditional on the slope of the preceded yield curve; if the index return was preceded by a positive (negative) yield curve spread, it is assigned to the normal (inverted) subsample. For both subsamples, the means of the excess returns are calculated which are the conditional means. McCown (2001) performs this process by using a binary instrumental variable that is defined as $S_{t-1} = 1$, given that the spread is positive. Logically, $S_{t-1} = 0$ when the yield curve is inverted, thus when the spread is positive. This returns the conditional excess returns for normal yield curves, where normal is defined as upward-sloping. Similarly, another binary variable is created to retrieve the conditional excess return for inverted yield curves, thus when the spread is negative: $S_{t-1} = 1$ when the yield spread is negative and $S_{t-1} = 0$ when the yield spread is positive.

While McCown (2001) exclusively examines the impact of the first preceding yield curve spread, this study extends the analysis by investigating the effects of 6 months and 12 months lagged spreads, since various studies suggest that the yield curve may influence the stock market at different time lags (Fama & French, 2019; Quinn et al., 2020). Besides performing the test with the German yield curve only, the test is also performed using the spreads of the US yield curve to enable for comparison between their effects. This enables a more direct comparison with the findings of McCown (2001).

The results for the test using the 1-month lagged effects of the yield curve spread are displayed in Table 2. All equity indices show positive average returns when the preceded yield curve was positive, both for the German and US yield curve. For the returns preceded by an inverted US yield curve, all equity indices show negative excess returns, on average. For the returns preceded by an inverted German yield curve, seven out of nine show negative excess returns, but SMIM and SMI show positive signs. However, the z-statistics for these two indices indicate that their conditional means are not significantly different. At 90% confidence level, it can be concluded that the conditional means for SDXK and MDAX differ significantly, implying that the probability of a type I error is less than 10%. In other words, the likelihood of incorrectly concluding that there is a difference when there is none is less than 10%. The other results are not statistically significant.

For the US yield curve, the signs of the conditional means are in line with expectations. However, only for AMX, the conditional means are statistically different at 90% confidence level.

Overall, from the results in Table 2, it cannot be concluded that either the German or the American yield curve has effects to the equity indices of Germany, the Netherlands, and Switzerland.

The results for the test using the 6-month lagged effects of the yield curve spread are displayed in Table 3. For both yield curves, the signs of the conditional means for all indices are in line with the expectation. However, when looking at the results based on the German yield curve, only the conditional means of DAX, MDAX, and SMCI are significantly different at 90% confidence level. Compared with the results based on the US yield curve, all results are statistically significant, except for DAX, MDAX, and AEX.

The results in Table 3, thus, indicate that the US yield curve has more predictive power than the German yield curve when looking 6 months into the future.

Table 4 displays the results for the test using the 12-month lagged effects of the yield curve spread. For the German yield curve, no statistically significant results are found. Therefore, the results are rather inconclusive. For six out of nine indices, the average of excess returns 12 months after a negative yield curve is even higher than the average of excess returns following a positive yield curve with a 12-month lag. This is not per se concerning and is also observed by McCown (2001) for one-month lag without statistical significance.

From this test, it can be concluded that the US yield curve may have some relationship with equity index returns as there are only 2 out of nine indices for which the results are statistically insignificant. For all indices, the signs of the conditional means are positive and negative for those preceded by a positive and negative US yield curve with a 12-month lag, respectively. For the US yield curve slope, there appears to be quite some spillover effect to other countries' economies in this context.

In short, this section reassessed the spillover effects that McCown (2001) found for the German and US yield curve inversions. It is found that the US yield curve inversions seem to have stronger relationships with the excess returns of the equity indices than the German yield curve inversions. The next section explains the methodology exploited to gain a better understanding of the effects that the German yield curve may have on the excess returns.

Table 2: Z-test of two sample means. The means are the monthly returns of the equity indices lagged with one month. A binary variable is used to indicate whether the spread was positive (normal) or negative (inverted) 1 month before the respective return. The p-values indicate the probability of a Type I error.

	German Yield Curve based				**US Yield Curve based**			
	mean_normal	**mean_inverted**	**z_statistic**	**p_value**	**mean_normal**	**mean_inverted**	**z_statistic**	**p_value**
DAX	0.5483	-0.0777	0.8923	0.3722	0.5408	-0.3627	1.1710	0.2416
SDXK	0.5266	-0.7445	1.6812	0.0927	0.4018	-0.5877	1.3574	0.1747
MDAX	0.7315	-0.6820	1.8713	0.0613	0.5449	-0.1928	1.0178	0.3088
AEX	0.4487	-0.2375	0.9774	0.3284	0.3995	-0.4009	1.1896	0.2342
ASCX	0.4515	-0.4266	1.1550	0.2481	0.3982	-0.5291	1.1521	0.2493
AMX	0.5268	-0.7189	1.5518	0.1207	0.4975	-0.9791	1.8120	0.0700
SMCI	0.5476	-0.4447	1.5160	0.1295	0.4279	-0.2382	0.8913	0.3728
SMIM	0.3730	0.1663	0.4088	0.6827	0.4733	-0.4953	1.5856	0.1128
SMI	0.3543	0.1696	0.3565	0.7215	0.4579	-0.5092	1.5371	0.1243

Table 3: Z-test of two sample means. The means are the monthly returns of the equity indices lagged with one month. A binary variable is used to indicate whether the spread was positive (normal) or negative (inverted) 6 months before the respective return. The p-values indicate the probability of a Type I error.

	German Yield Curve based				**US Yield Curve based**			
	mean_normal	**mean_inverted**	**z_statistic**	**p_value**	**mean_normal**	**mean_inverted**	**z_statistic**	**p_value**
DAX	0.6961	-0.7044	1.8081	0.0706	0.6681	-0.6002	1.5248	0.1273
SDXK	0.5114	-0.7636	1.6323	0.1026	0.4932	-0.7454	1.6123	0.1069
MDAX	0.7283	-0.7576	1.8310	0.0671	0.6039	-0.2776	1.1186	0.2633
AEX	0.5365	-0.6293	1.5754	0.1152	0.5281	-0.6828	1.7932	0.0729
ASCX	0.4502	-0.4764	1.1818	0.2373	0.4548	-0.5713	1.2738	0.2027
AMX	0.4413	-0.4568	1.0628	0.2879	0.5633	-1.0444	1.8705	0.0614
SMCI	0.5825	-0.6452	1.7806	0.0750	0.5805	-0.5980	1.7141	0.0865
SMIM	0.4410	-0.1168	1.0042	0.3153	0.5494	-0.7975	2.6739	0.0075
SMI	0.4423	-0.1916	1.1204	0.2625	0.5517	-0.8436	2.7798	0.0054

Table 4: Z-test of two sample means. The means are the monthly returns of the equity indices lagged with one month. A binary variable is used to indicate whether the spread was positive (normal) or negative (inverted) 12 months before the respective return. The p-values indicate the probability of a Type I error.

	German Yield Curve based				**US Yield Curve based**			
	mean_normal	**mean_inverted**	**z_statistic**	**p_value**	**mean_normal**	**mean_inverted**	**z_statistic**	**p_value**
DAX	0.4047	0.4565	-0.0738	0.9412	0.5030	-0.2371	0.8038	0.4215
SDXK	0.3089	0.0270	0.4039	0.6863	0.5305	-1.3238	2.1302	0.0332
MDAX	0.5318	-0.0034	0.6912	0.4894	0.6879	-0.9867	1.9695	0.0489
AEX	0.2826	0.3851	-0.1451	0.8846	0.5291	-1.0758	1.8432	0.0653
ASCX	0.2121	0.4837	-0.3846	0.7005	0.4062	-0.6728	1.2007	0.2299
AMX	0.1886	0.5665	-0.4898	0.6243	0.5200	-1.2824	1.8153	0.0695
SMCI	0.3754	0.1675	0.3233	0.7465	0.5360	-0.9262	1.7502	0.0801
SMIM	0.2473	0.6741	-0.7952	0.4265	0.5669	-1.0968	3.0992	0.0019
SMI	0.2418	0.6243	-0.7050	0.4808	0.5550	-1.1268	3.0491	0.0023

3.3 Methodology

As described, the retrieved data is characterized by a time-series dimension. The benchmark model of this research is the FF5M model displayed in equation 7. To capture the relationship that changes in the German yield spread have with the excess returns of the German, Dutch, and Swiss stock markets, this model is expanded with variations of the yield curve factor.

To assess the relationship between the changes in the German yield spread and the asset returns, the FF5M model is expanded with the month-to-month difference in the German yield spread, YC_t, following Schuermann and Stiroh (2006), Killins et al. (2021), Killins and Chen (2022). In other words, YC_t is the difference between the yield spread at time t and t-1. This is shown in equation 13.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 WML_t + \beta_7 YC_t + \varepsilon_{it} \quad (13)$$

The second hypothesis of this research states that there is lagged effects from German yield spread changes. To test this, the model in equation 13 is adapted to include a lagged variable of the changes in the yield spreads as represented in equation 14. This lagged variable is represented by YC_{t-k}. Given that various authors have identified lagged effects from the yield curve on stock market performance, the model is estimated for different lag periods. Specifically, k is assigned values of 3, 6, and 12 months. For robustness, the model is also estimated with lags of 9 and 24 months for the yield spread.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 WML_t + \beta_7 YC_{t-k} + \varepsilon_{it} \quad (14)$$

Next, it is tested whether changes in the German yield spreads affect the excess returns differently when the yield curve is inverted following hypothesis 3. To do so, equations 13 and 14 are expanded with interaction terms, $YC_t D_t$ and $YC_{t-k} D_{t-k}$, respectively. These models, defined in equations 15 and 16, are defined as threshold models following previous literature (Baur & Todovora, 2018, Killins et al., 2021; Killins & Chen, 2022). If the coefficient of this interaction term is significantly different from 0, it can be concluded that changes of the yield spread during inversion affect the excess returns differently than when the yield curve is not inverted.

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 WML_t + \beta_7 YC_t + \beta_8 YC_t D_t + \varepsilon_{it} \quad (15)$$

$$R_{it} - R_{ft} = \alpha_i + \beta_1(R_{mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \beta_4 RMW_t + \beta_5 CMA_t + \beta_6 WML_t + \beta_7 YC_{t-k} + \beta_8 YC_{t-k} D_{t-k} + \varepsilon_{it} \quad (16)$$

To ensure the robustness of the results, diagnostic tests were performed. The Breusch-Godfrey test did not provide significant evidence of autocorrelation. However, the Breusch-Pagan test indicated significant evidence of heteroskedasticity in the residuals. To account for this, White's (1980) robust standard errors are used.

3.3.1 Ordinary Least Squared (OLS) Regressions

The models introduced in this research are examples of OLS regressions. This section, therefore, covers the working and underlying assumptions of such regressions and is a summary of Brooks (2019). After explaining how the coefficients in the models are estimated and how the explanatory power of the models can be assessed, the results are discussed in Chapter 4.

k independent variables, denoted by *x*, may be related to dependent or effect variable, *y*, as illustrated by the multivariate linear model defined in equation 17:

$$y_i = \alpha + \sum_{j=1}^{k} \beta_j x_{ij} + u_i, i = 1, 2, \dots, N \quad (17)$$

Here, *N* is the number of observations in the sample used. α represents a constant. β_j is the coefficient respective to independent variable x_j. u_i represents the residual term for each observation and is the difference between the estimated or fitted value of the dependent variable, $\widehat{y_i}$ and the actual value, y_i. This is represented by equations 18 and 19:

$$\widehat{y_i} = \hat{\alpha} + \sum_{j=1}^{k} \widehat{\beta_j} x_{ij}, i = 1, 2, \dots, N \quad (18)$$

$$u_i = y_i - \widehat{y_i}, i = 1, 2, \dots, N \quad (19)$$

As aforementioned, the method of least squares is applied to estimate the coefficients, α and β. This method minimizes the residuals' sum of squares (RSS) to allow for this estimation:

$$\min \sum_{i=1}^{N} u_i^2 = \sum_{i=1}^{N} (y_i - \widehat{y_i}) = \sum_{i=1}^{N} (y_i - \hat{\alpha} - \sum_{j=1}^{k} \widehat{\beta_j} x_{ij})^2, i = 1,2, \dots, N \quad (20)$$

To explain how the coefficients can be estimated, equation 17 is written in matrix form in equation 21. $\boldsymbol{X}$ represents the explanatory variables and $\boldsymbol{\beta}$ represents the coefficients, including the constant term. The residuals are stored in $\boldsymbol{u}$. Finally, equation 22 shows how the coefficients are estimated.

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{u} \tag{21}$$

$$\widehat{\boldsymbol{\beta}} = (\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{X}'\boldsymbol{y} \tag{22}$$

Brooks (2019) discusses the R^2 and the adjusted R^2 as goodness of fit statistics to measure how well a model explains the variations in the fitted variable. To derive R^2, the unconditional mean of y is used, denoted by $\bar{y}$. The unconditional mean is used to retrieve the total sum of squares (TSS) as indicated by equation 23. This equation also shows that TSS can be split into the part explained by the model (ESS) and the part that remains unexplained (RSS). With these measures, R^2 can be estimated as explained in equation 25. In general, a value close to 1 for R^2 indicates that the model can explain almost all variability of y. Similarly, a value of R^2 close to 0 means that the model is not able to capture variability in the dependent variable to a large extent.

$$TSS = \sum_{i=1} (y_i - \hat{y}_i)^2 = ESS + RSS \tag{23}$$

$$ESS = \sum_{i=1} (y_i - \bar{y})^2 \tag{24}$$

$$R^2 = \frac{ESS}{TSS} = \frac{TSS - RSS}{TSS} \tag{25}$$

However, as R^2 never decreases by adding independent variables to the model, the adjusted R^2, or $\bar{R}^2$, is introduced. This measure takes the number of independent variables into account as shown in equation 18. If k increases, $\bar{R}^2$ decreases given that R^2 does not increase significantly to counterbalance it. In other words, it incorporates a penalty when variables are used that do not add significant explanatory power to the model. Thus, while the primary focus of this research is to explore the relationship between stock market performance and the yield curve rather than extending FF5M model, this metric can help assess whether incorporating a yield curve variable enhances the model's explanatory capability.

$$\bar{R}^2 = 1 - [\frac{N-1}{N-k}(1 - R^2)] \tag{26}$$

4. Results

As discussed in section 3.3, four different models are analyzed. First, the analysis without any yield curve factors is conducted to establish the baseline coefficients for the FF5M model. All subsequent models are extensions of the FF5M model. The next model extends the baseline by adding a variable that captures changes in the yield spread (YC). The third model also uses changes in the yield spread but incorporates lagged versions of this variable at 3, 6, 9, 12, and 24 months. The final model introduces an interaction term, “YC * D,” which is the product of changes in the yield spread and a dummy variable that is 1 when the German yield curve is inverted and 0 otherwise. This last model is analyzed both as an unlagged version and with lags at 3, 6, 9, 12, and 24 months, aiming to capture any asymmetry in the effects of yield spread changes on the stock market specifically when the yield curve is inverted.

The regression outputs are shown in Tables 5 to 17. The first number in each cell represents the coefficients. The numbers in brackets refer to White’s (1980) robust standard errors. The R^2 and adjusted R^2 are measures of the explanatory power of the models.

4.1 FF5M

Table 5 presents the results from the original FF5M model. The market risk factor is statistically significant at the 1 percent confidence level for all equity indices over the period November 1990 to December 2023. The coefficients range from approximately 0.47 for SMIM to 0.77 for DAX. Thus, an increase of Mkt-RF by 100 basis points (bp) corresponds to an increase in excess return of 47 bp for SMIM and 77 bp for DAX, on average. Notably, the coefficients for the German and Dutch equity indices are higher than 0.71, whereas the coefficients for the Swiss equity indices are all lower than 0.66. Mkt-RF is the variable with the greatest explanatory power across all indices, except for the large and mid-cap Swiss indices. This indicates that the primary source of systematic, or common, variation affecting the returns of most indices is the European market factor. This finding is consistent with Schuermann and Stiroh (2006), who concluded that market returns are the most influential factor for returns.

For the SMB factor, DAX, AEX, SMI, and SMIM exhibit negative coefficients, which can be attributable to the fact that these indices, except for SMIM, consist of large-cap firms that suffer from size risk to a greater extent. Among the German indices, DAX has the lowest coefficient at approximately -0.57, increasing to 0.28 for the mid-cap index MDAX, and 0.55 for the small-cap index SDAX. Despite an upward trend from large-cap to small-cap indices in Germany, this pattern is not observed for the Dutch and Swiss indices. For all indices, the coefficients are statistically significant at the 99% confidence level, except for ASCX and SMCI, where the coefficients are statistically significant at the 95% confidence level.

For the HML factor, coefficients range from 0.0066 to 0.2624 for SDXK and AMX, respectively. However, only the AMX shows a statistically significant result.

The coefficients for RMW are negative across all indices, indicating a negative relationship with excess returns of the indices, with significant results observed only for Swiss large-cap and small-cap indices at 90% and 99% confidence levels, respectively.

Statistically significant results for the CMA factor are found for DAX, AEX, AMX, ASCX, and SMCI at the 99% confidence level. All the signs are negative, once again suggesting a likely negative relationship between this factor and the excess returns of the indices.

The momentum factor, WML, is statistically significant at the 90% confidence level for DAX and MDAX. On average, a 100 bp increase in this factor corresponds to a decrease of approximately 11 bp in the excess returns of these indices. Except for SMI and SMIM, the other indices also show negative coefficients. However, DAX and MDAX are the only indices with statistically significant coefficients among the studied indices.

The adjusted R^2 values range from approximately 47% for SMIM to 66% for DAX. This means that the model can explain approximately 47% to 66% of the variability in the excess returns. Notably, the adjusted R^2 is around 60% for most indices, but only around 48% for SMI and SMIM.

4.2 FF5M Extended with Unlagged Changes in the German Yield Curve

Table 6 shows the results for the FF5M model extended with the unlagged month-to-month changes in the German yield curve. For the German indices, positive coefficients for the yield curve factor are estimated, but only the DAX shows a statistically significant coefficient at the 95% confidence level. On average, an increase of 100 bp in the month-to-month change of the German yield curve corresponds to an increase of approximately 210 bp in the excess return for the DAX. This is in line with McCown (2001) who argues that there is a positive relationship between the size of the term spread and the risk premium. Moreover, Fama and French (1989) demonstrate that the risk premium tends to be lower than average when the term spread is low. It can be argued that positive changes in the yield spread lead to higher excess returns. This is because a positive change either increases the term spread or, if the term spread is currently negative, shifts it towards becoming positive.

Some indication of a spillover effect is observed for the AEX and ASCX, both of which have positive, statistically significant coefficients of approximately 1.67 and 1.89, respectively. No statistically significant results are found for the Swiss indices, and SMIM shows a negative sign.

By adding the yield curve factor to the FF5M model, the explanatory power, as measured by the adjusted R^2, increases only marginally. The largest increase in the adjusted R^2 is observed for the DAX. In this case, adding the yield curve factor increases the explanatory power of the model from approximately 65.99% to 66.39%. This aligns with the findings of Killins and Chen (2022) and Schuermann and Stiroh (2006), who observe that extending the Fama-French Three Factor model only marginally affects the explanatory power of the model.

4.3 FF5M Extended With Lagged Changes in the German Yield Curve

McCown (2001) also argues that negative risk premiums occur for various long-term financial assets during periods preceded by inverted yield curves. Additionally, Estrella and Mishkin (1995) find that the yield curve spread is a good indicator of the probability of a recession, with a lead time of one to two years. To explore this further, this model incorporates different lag periods to test the validity of this claim and to identify the time frame within which the effect of the inverted yield curve is observed.

4.3.1 3-Month Lag

Table 7 shows the results for the FF5M model extended with a 3-month lagged yield curve factor. For the German indices, the signs of the coefficients for “YC” change compared to the model with the unlagged yield curve factor. Although the negative coefficients for DAX and MDAX are insignificant, the coefficient for SDXK is -1.69 and statistically significant at the 95% confidence level. This means that an increase (decrease) in the German yield curve spread of 100 bp is associated with a decrease (increase) of 169 bp in the excess return of SDXK, with this effect occurring 3 months later. The negative coefficients are somewhat surprising, indicating that a flattening of the yield curve is associated with positive excess returns. Moreover, the results are not supported by majority of the previous literature, as Boudoukh et al. (1993) analyze U.S. stocks and find that risk premiums are most likely to be negative during periods preceded by inverted yield curves. These findings are, however, consistent with the paper by Killins and Chen (2022), which identifies a statistically significant negative relationship between excess returns and a one-month lagged variable representing changes in the yield spread.

The coefficients for the Dutch and Swiss indices are not statistically significant, and the signs are inconsistent. For AEX, ASCX, and SMCI, negative coefficients are found. In contrast, the other indices have positive coefficients. Thus, it cannot be concluded that there is a spillover effect from changes in the German yield curve to other countries at a 3-month lag.

Notably, adding the 3-month lagged yield curve factor marginally decreases the explanatory power for most Dutch and Swiss indices. For example, the adjusted R^2 decreases from 47.82% for the FF5M model in equation 5 to 47.71% for the model including the yield curve factor lagged by 3 months. This contrasts with Killins and Chen (2022) and Schuermann and Stiroh (2006), who find a marginal increase in the explanatory power of their model.

4.3.2 6-Month Lag

Table 8 depicts the estimated FF5M model extended with the yield curve factor lagged by 6 months. Notably, no statistically significant effects are found for the Dutch and Swiss indices, indicating no lagged spillover effect from the German yield curve to the Dutch and Swiss stock markets. However, a statistically significant relationship is found between the lagged yield curve factor and the excess returns of MDAX and SDXK at the 90% confidence level. On average, an increase (decrease) of 100 bp in the yield curve spread difference is associated with a decrease (increase) of approximately 153 bp and 142 bp in the excess returns of MDAX and SDXK, respectively. This is furthermore supported by Killins and Chen (2022), who identify a statistically significant negative relationship between excess returns and a one-month lagged variable representing changes in the yield spread.

The explanatory power of the model does not change significantly. This is indicated by marginal changes in the adjusted R^2. The adjusted R^2 for the German indices and SMCI slightly increases, whereas it decreases for the other indices.

4.3.3 12-Month Lag

The results for the FF5M model extended with the 12-month lagged yield curve factor are displayed in Table 9. No statistically significant relationships are found between the lagged yield curve factor and the excess returns of the equity indices. Therefore, it cannot be concluded that there is a spillover effect with a 12-month lag. This somewhat aligns with the findings of Fama and French (2019), who do not find evidence that a flattening yield curve predicts underperformance of the stock markets over a 12-month period. The signs of the coefficients are also inconsistent: DAX, MDAX, AEX, and ASCX have negative coefficients for the lagged changes in the German yield curve spread, while the other five indices have positive coefficients.

Furthermore, with the inclusion of the additional factor, the explanatory power of all models decreases marginally, except for SMCI, where the adjusted R^2 increases from 60.73% to 60.78%. The largest decrease is observed for SMIM, with the adjusted R^2 decreasing from 46.34% to 46.20%. In contrast, the smallest decrease occurs for DAX, with the adjusted R^2 decreasing from 65.99% to 65.95%.

Table 5: The FF5M model. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2725	0.1856	0.0198	0.1044	-0.0609	-0.0163	0.1604	0.1604	0.1815
	(0.194)	(0.193)	(0.196)	(0.186)	(0.206)	(0.181)	(0.182)	(0.180)	(0.179)
Mkt-RF	0.7683***	0.7417***	0.7311***	0.7169***	0.7564***	0.7358***	0.4838***	0.4685***	0.6509***
	(0.051)	(0.045)	(0.045)	(0.049)	(0.052)	(0.043)	(0.042)	(0.041)	(0.043)
SMB	-0.5693***	0.2764***	0.5496***	-0.4274***	0.3227***	0.2254**	-0.504***	-0.5373***	0.1853**
	(0.104)	(0.086)	(0.099)	(0.090)	(0.103)	(0.088)	(0.083)	(0.085)	(0.088)
HML	0.0739	0.0809	0.0066	0.0412	0.2624**	0.1565	0.0806	0.0667	0.119
	(0.128)	(0.119)	(0.109)	(0.133)	(0.157)	(0.128)	(0.137)	(0.134)	(0.132)
RMW	-0.2643	-0.1621	-0.1206	-0.1978	-0.0958	-0.1759	-0.2247*	-0.1675	-0.3165***
	(0.177)	(0.150)	(0.147)	(0.148)	(0.179)	(0.142)	(0.127)	(0.131)	(0.123)
CMA	-0.6297***	-0.2303	-0.1578	-0.4435***	-0.5298***	-0.616***	-0.2834	-0.2265	-0.5708***
	(0.145)	(0.150)	(0.136)	(0.171)	(0.182)	(0.151)	(0.186)	(0.181)	(0.169)
WML	-0.1148*	-0.1131*	-0.1303	-0.0659	-0.0786	-0.0280	0.0081	0.0075	-0.0562
	(0.061)	(0.066)	(0.053)	(0.055)	(0.066)	(0.052)	(0.052)	(0.050)	(0.056)
R^2	66.50%	59.66%	61.73%	63.26%	58.54%	64.66%	48.61%	47.15%	61.33%
Adj. R^2	65.99%	59.04%	61.15%	62.70%	57.90%	64.12%	47.82%	46.34%	60.73%

*** *$p < 0.01$.*
** *$p < 0.05$.*
* *$p < 0.1$.*

Table 6: The FF5M model extended with the yield curve factor. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor YC is the change in German yield spread. The yield curve factors are unlagged. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2860	0.1906	0.0253	0.1152	-0.0546	-0.0045	0.162	0.1603	0.1882
	(0.188)	(0.193)	(0.196)	(0.185)	(0.207)	(0.181)	(0.182)	(0.180)	(0.179)
Mkt-RF	0.7629***	0.7397***	0.7289***	0.7126***	0.7539***	0.731***	0.4832***	0.4686***	0.6483***
	(0.042)	(0.045)	(0.045)	(0.049)	(0.052)	(0.043)	(0.041)	(0.088)	(0.043)
SMB	-0.5897***	0.2688***	0.5414***	-0.4436***	0.3131***	0.2076**	-0.5064***	-0.5371***	0.1752**
	(0.106)	(0.088)	(0.101)	(0.090)	(0.105)	(0.088)	(0.086)	(0.088)	(0.091)
HML	0.0682	0.0788	0.0043	0.0367	0.2598**	0.1515	0.0799	0.0668	0.1162
	(0.128)	(0.119)	(0.109)	(0.134)	(0.158)	(0.130)	(0.138)	(0.134)	(0.132)
RMW	-0.2599*	-0.1604	-0.1188	-0.1943	-0.0938	-0.172	-0.2242**	-0.1675	-0.3143**
	(0.177)	(0.151)	(0.148)	(0.148)	(0.179)	(0.142)	(0.128)	(0.131)	(0.123)
CMA	-0.6430***	-0.2352*	-0.1632	-0.4541***	-0.5361***	-0.6275***	-0.285**	-0.2263*	-0.5774***
	(0.142)	(0.151)	(0.136)	(0.173)	(0.183)	(0.151)	(0.187)	(0.182)	(0.169)
WML	-0.1135**	-0.1126**	-0.1298***	-0.0648	-0.0779	-0.0269	0.0082	0.0075	-0.0555
	(0.061)	(0.066)	(0.054)	(0.056)	(0.066)	(0.053)	(0.053)	(0.051)	(0.056)
YC	2.1036**	0.7844	0.8487	1.6666**	0.9827	1.8268**	0.2477	-0.0212	1.0384
	(1.004)	(0.971)	(0.913)	(1.014)	(0.066)	(0.945)	(1.009)	(1.002)	(0.893)
R^2	66.98%	59.74%	61.84%	63.63%	58.65%	65.11%	48.63%	47.15%	61.49%
Adj. R^2	66.39%	59.02%	61.15%	62.98%	57.90%	64.48%	47.70%	46.20%	60.80%

*** *$p < 0.01$.*
** *$p < 0.05$.*
* *$p < 0.1$.*

Table 7: The FF5M model extended with the 3-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2617	0.1744	0.0066	0.1023	-0.0572	-0.0223	0.1625	0.1651	0.1735
	(0.1928)	(0.1932)	(0.1958)	(0.1873)	(0.2068)	(0.1821)	(0.1817)	(0.1796)	(0.1795)
Mkt-RF	0.771***	0.7445***	0.7344***	0.7174***	0.7555***	0.7373***	0.4833***	0.4673***	0.6529***
	(0.0511)	(0.0445)	(0.0441)	(0.0491)	(0.0523)	(0.0434)	(0.0419)	(0.0410)	(0.0428)
SMB	-0.5515***	0.2948***	0.5713***	-0.4240***	0.3165***	0.2353***	-0.5075***	-0.5451***	0.1985***
	(0.1048)	(0.0878)	(0.1003)	(0.0905)	(0.1043)	(0.0882)	(0.0844)	(0.0856)	(0.0895)
HML	0.0763	0.0833	0.0095	0.0417	0.2616**	0.1578	0.0801	0.0657	0.1208
	(0.1269)	(0.1195)	(0.1083)	(0.1326)	(0.1570)	(0.1279)	(0.1372)	(0.1334)	(0.1318)
RMW	-0.2488*	-0.1460	-0.1016	-0.1948	-0.1012	-0.1672	-0.2277**	-0.1743	-0.3050**
	(0.1781)	(0.1485)	(0.1461)	(0.1472)	(0.1799)	(0.1412)	(0.1271)	(0.1311)	(0.1215)
CMA	-0.6232***	-0.2236*	-0.1499	-0.4423***	-0.5321***	-0.6124***	-0.2847	-0.2293*	-0.5660***
	(0.1438)	(0.1520)	(0.1355)	(0.1724)	(0.1816)	(0.1515)	(0.1863)	(0.1801)	(0.1706)
WML	-0.1198**	-0.1182**	-0.1364***	-0.0668	-0.0768	-0.0308	0.0090	0.0097	-0.0599
	(0.0618)	(0.0664)	(0.0526)	(0.0542)	(0.0659)	(0.0521)	(0.0530)	(0.0509)	(0.0559)
YC	-1.3843	-1.4317	-1.6881**	-0.2706	0.4787	-0.7677	0.2704	0.6066	-1.0280
	(0.8892)	(1.1022)	(0.9053)	(1.0068)	(0.9766)	(0.8825)	(0.8512)	(0.8544)	(0.8115)
R^2	66.71%	59.93%	62.13%	63.27%	58.56%	64.74%	48.63%	47.23%	61.48%
Adj. R^2	66.11%	59.21%	61.45%	62.61%	57.82%	64.11%	47.71%	46.28%	60.79%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 8: The FF5M model extended with the 6-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2620	0.1733	0.0085	0.1020	-0.0677	-0.0199	0.1635	0.1643	0.1735
	(0.1933)	(0.1921)	(0.1953)	(0.1847)	(0.2051)	(0.1809)	(0.1825)	(0.1806)	(0.1793)
Mkt-RF	0.7770***	0.7520***	0.7405***	0.7189***	0.7621***	0.7388***	0.4813***	0.4652***	0.6577***
	(0.0517)	(0.0449)	(0.0448)	(0.0484)	(0.0520)	(0.0427)	(0.0422)	(0.0413)	(0.0432)
SMB	-0.5674***	0.2787***	0.5517***	-0.4270***	0.3239***	0.2261***	-0.5045***	-0.5380***	0.1867**
	(0.1036)	(0.0847)	(0.0979)	(0.0898)	(0.1023)	(0.0882)	(0.0836)	(0.0851)	(0.0879)
HML	0.0631	0.0682	-0.0052	0.0387	0.2554**	0.1527	0.0837	0.0708	0.1107
	(0.1277)	(0.1209)	(0.1083)	(0.1330)	(0.1565)	(0.1277)	(0.1384)	(0.1348)	(0.1323)
RMW	-0.2635*	-0.1610	-0.1197	-0.1976	-0.0953	-0.1755	-0.2250*	-0.1678	-0.3158**
	(0.1775)	(0.1510)	(0.1468)	(0.1479)	(0.1789)	(0.1418)	(0.1275)	(0.1311)	(0.1228)
CMA	-0.6267***	-0.2268*	-0.1546	-0.4429***	-0.5279***	-0.6149***	-0.2843**	-0.2276*	-0.5685***
	(0.1469)	(0.1516)	(0.1352)	(0.1715)	(0.1823)	(0.1508)	(0.1867)	(0.1816)	(0.1703)
WML	-0.1113**	-0.1089**	-0.1265***	-0.0651	-0.0763	-0.0268	0.0070	0.0061	-0.0535
	(0.0615)	(0.0682)	(0.0517)	(0.0546)	(0.0650)	(0.0522)	(0.0525)	(0.0504)	(0.0553)
YC	-1.3008	-1.5294*	-1.4163*	-0.3003	-0.8450	-0.4541	0.3787	0.4928	-1.0047
	(0.8846)	(1.0134)	(0.8901)	(0.8657)	(0.9487)	(0.8419)	(0.8322)	(0.8268)	(0.8399)
R^2	66.69%	59.97%	62.01%	63.27%	58.62%	64.69%	48.64%	47.20%	61.48%
Adj. R^2	66.09%	59.25%	61.33%	62.62%	57.87%	64.06%	47.72%	46.25%	60.79%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 99: The FF5M model extended with the 12-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2734	0.1860	0.0195	0.1049	-0.0615	-0.0156	0.1602	0.1602	0.1802
	(0.1938)	(0.1929)	(0.1961)	(0.1860)	(0.2064)	(0.1820)	(0.1821)	(0.1803)	(0.1787)
Mkt-RF	0.7690***	0.7421***	0.7308***	0.7172***	0.7560***	0.7362***	0.4836***	0.4684***	0.6500***
	(0.0514)	(0.0447)	(0.0451)	(0.0490)	(0.0522)	(0.0431)	(0.0420)	(0.0412)	(0.0424)
SMB	-0.5715***	0.2754***	0.5505***	-0.4284***	0.3242***	0.2238***	-0.5034***	-0.5368***	0.1884**
	(0.1050)	(0.0859)	(0.0993)	(0.0901)	(0.1038)	(0.0883)	(0.0839)	(0.0854)	(0.0882)
HML	0.0766	0.0822	0.0055	0.0425	0.2606**	0.1584	0.0798	0.0662	0.1150
	(0.1273)	(0.1195)	(0.1096)	(0.1322)	(0.1566)	(0.1277)	(0.1371)	(0.1337)	(0.1311)
RMW	-0.2648*	-0.1623	-0.1204	-0.1980	-0.0955	-0.1762	-0.2246*	-0.1674	-0.3158**
	(0.1764)	(0.1500)	(0.1474)	(0.1479)	(0.1797)	(0.1414)	(0.1276)	(0.1312)	(0.1233)
CMA	-0.6340***	-0.2323*	-0.1561	-0.4455***	-0.5269***	-0.6190***	-0.2823**	-0.2256*	-0.5646***
	(0.1456)	(0.1508)	(0.1367)	(0.1709)	(0.1803)	(0.1506)	(0.1859)	(0.1810)	(0.1677)
WML	-0.1151**	-0.1132**	-0.1302***	-0.0660	-0.0784	-0.0282	0.0081	0.0075	-0.0558
	(0.0613)	(0.0659)	(0.0533)	(0.0550)	(0.0658)	(0.0524)	(0.0525)	(0.0506)	(0.0557)
YC	-0.6515	-0.3134	0.2585	-0.2986	0.4493	-0.4634	0.1774	0.1224	0.9523
	(0.8878)	(1.0622)	(0.7822)	(0.9401)	(1.0464)	(0.8959)	(0.8479)	(0.8496)	(0.8180)
R^2	66.55%	59.67%	61.74%	63.28%	58.56%	64.69%	48.62%	47.15%	61.47%
Adj. R^2	65.95%	58.95%	61.06%	62.62%	57.82%	64.06%	47.70%	46.20%	60.78%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

4.4 FF5M Extended with the Interaction Term

The models discussed in this section are defined by equations 15 and 16. The objective is to identify any asymmetry in the impact of yield spread changes on the stock market, particularly during periods when the yield curve is inverted. In addition to the interaction term, the model still includes the first yield curve variable representing changes in the yield spread. If the coefficient of the interaction term significantly differs from zero, it suggests the presence of an asymmetric effect. This indicates that not all variations in excess returns can be explained by the variable capturing all yield spread changes. Instead, by adding this variable conditioned on the yield curve being inverted, it captures some more excess return volatility.

4.4.1 Unlagged

Table 10 presents the results for adding the unlagged yield curve factor and the unlagged interaction term. For DAX, the coefficients for changes in the yield spread and the interaction term have different signs, being approximately 2.11 and -0.03, respectively. However, only the coefficient for the changes in the yield curve spread is statistically significant at the 95% confidence level. Similar differing signs for the coefficients are observed for some other indices. Based on the estimations presented in Table 10, it is difficult to draw strong conclusions about asymmetrical effects, as there are no significant coefficients for the "Δ German Spread * D" variable. This is not consistent with prior literature stating negative risk premiums occur for various long-term financial assets in periods preceded by inverted yield curves (McCown, 2001). Additionally, Killins and Chen (2022) provide further evidence supporting this notion, demonstrating that negative changes in the yield curve have a significant negative impact on equity returns for the companies in their sample.

4.4.2 3-Month Lag

Table 11 displays results similar to those in Table 10, but with the yield curve factors lagged by 3 months. For MDAX, SDXK, AMX, SMI, SMIM, and SMCI, the coefficients have different signs, suggesting possible asymmetrical effects. However, the results are not statistically significant. Only the coefficient for changes in the yield curve for SDXK is statistically significant at the 90% confidence level. Therefore, it cannot be concluded that there are significant asymmetric effects. Similarly to the unlagged variable, these findings are not consistent with previous literature.

4.4.3 6-Month Lag

The interaction term and changes in the yield spread are lagged by 6 months and used to extend the FF5M model. The results are shown in Table 12. The coefficients for the interaction term range from -0.41 for SMI to 0.64 for MDAX. However, no statistically significant results are found for the interaction term, indicating a deviation from past literature, and suggesting no special effect of an inverted yield curve on excess returns.

4.4.4 12-Month Lag

Table 13 presents results for the interaction term lagged by 12 months, which are very similar to those in the previous table.

The coefficients of the variable "YC" seem to be insignificant for all indices. The interaction term tends to show insignificant results for all but the Swiss large and mid-cap indices, consistent with the results from Table 15. These two coefficients remain negative but are now significant at the 95% confidence level. The adjusted R^2 does not deviate much from the previous table; it ranges between 46.73% (SMIM) and 65.93% (DAX).

4.5 Robustness

This section runs additional models and compares the results with those found earlier. Specifically, the models are estimated for 9- and 24-month lags for which the results can be found in the appendix (Table 14-17). Consistent with Fama and French (2019), no significant results are found at the 12-month lag. Therefore, the 9-month and 24-month lags are used to assess the robustness of the results.

Statistically significant results for the 9-month lagged changes in German yield spread are only found for ASCX. This differs from the models using 6- and 12-month lags that do not find any significant results for the Dutch and Swiss indices. In line with the results for the 6-month lagged models, the 9-month lagged yield curve factor persists to be negative but statistically insignificant. The results of the FF5M model extended with a 9-month lagged yield curve factor are visible in table 14.

Whereas no significant coefficients are found for the 12-month lagged changes in German yield spread, a positive significant coefficient for AMX is estimated using the 24-month lagged version. This may suggest that there are some long-term effects contradicting Fama and French (2019). The results for the 24-month lagged yield spread changes are displayed in Table 15.

Table 16 shows the results of the FF5M model expanded by adding a 9-month lagged interaction term and 9-month lagged changes in the German yield spread. The variable representing changes in the yield spread has positive coefficients for the Dutch and Swiss indices, while the coefficients for Germany are negative. The interaction term has generally an insignificant coefficient, except for the Swiss large and mid-cap indices, where it is negative and significant at the 90% confidence level. This contradicts the results for the 6-month lags where no significant results are found for the interaction term. However, it somewhat corresponds with the results for the 12-month lag where coefficient is also negative and statistically significant for the Swiss large and mid-cap indices.

Table 17 shows the results of the FF5M model expanded by adding a 24-month lagged interaction term and 9-month lagged changes in the German yield spread. The coefficients for the Fama-French factors and Carhart's (1997) momentum factor deviate marginally from those found for the 12-month lagged model. The coefficient for the interaction term is only significant for AMX which is the only deviation from the estimations using a 12-month lagged interaction term and yield spread changes.

It is important to note that significant results are often missing across different models and lag periods, indicating a degree of inconsistency. The lack of significant results indicates that extending the FF5M model is not a suitable method to discover the relationship between the yield curve and the stock market performance following Petkova (2006) and Leite et al. (2020).

Table 10: The FF5M model extended with the yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The yield curve factors are not lagged. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2819	0.3075	0.0928	0.1246	-0.0721	-0.0541	0.1211	0.1323	0.2123
	(0.2070)	(0.1986)	(0.2057)	(0.1893)	(0.2178)	(0.1880)	(0.1980)	(0.1962)	(0.1945)
Mkt-RF	0.7630***	0.7365***	0.7270***	0.7123***	0.7544***	0.7324***	0.4843***	0.4693***	0.6476***
	(0.0511)	(0.0446)	(0.0450)	(0.0484)	(0.0524)	(0.0430)	(0.0413)	(0.0405)	(0.0429)
SMB	-0.5892***	0.2529***	0.5322***	-0.4449***	0.3155***	0.2144**	-0.5008***	-0.5332***	0.1719*
	(0.1065)	(0.0861)	(0.1001)	(0.0898)	(0.1060)	(0.0891)	(0.0861)	(0.0878)	(0.0921)
HML	0.0684	0.0735	0.0013	0.0363	0.2606*	0.1538	0.0817	0.0680	0.1151
	(0.1280)	(0.1186)	(0.1098)	(0.1341)	(0.1580)	(0.1296)	(0.1378)	(0.1343)	(0.1323)
RMW	-0.2600	-0.1564	-0.1165	-0.1940	-0.0944	-0.1737	-0.2256*	-0.1685	-0.3135**
	(0.1778)	(0.1514)	(0.1483)	(0.1486)	(0.1797)	(0.1423)	(0.1276)	(0.1309)	(0.1234)
CMA	-0.6434***	-0.2240	-0.1567	-0.4532***	-0.5377***	-0.6323***	-0.2889	-0.2290	-0.5751***
	(0.1429)	(0.1527)	(0.1379)	(0.1737)	(0.1843)	(0.1520)	(0.1880)	(0.1830)	(0.1712)
WML	-0.1134*	-0.1138*	-0.1305**	-0.0649	-0.0777	-0.0263	0.0087	0.0078	-0.0558
	(0.0611)	(0.0660)	(0.0542)	(0.0557)	(0.0659)	(0.0526)	(0.0527)	(0.0508)	(0.0560)
YC * D	-0.0249	0.7022	0.4056	0.0568	-0.1056	-0.2978	-0.2456	-0.1681	0.1449
	(0.4273)	(0.4857)	(0.4895)	(0.4148)	(0.4678)	(0.4240)	(0.4042)	(0.3870)	(0.4200)
YC	2.1078**	0.6641	0.7792	1.6569	1.0008	1.8778**	0.2898	0.0076	1.0136
	(1.0079)	(0.9692)	(0.9236)	(1.0112)	(1.0704)	(0.9403)	(1.0211)	(1.0121)	(0.9004)
R^2	66.98%	61.94%	60.03%	63.64%	58.65%	65.16%	48.68%	47.18%	61.50%
Adj. R^2	66.30%	61.15%	59.20%	62.89%	57.80%	64.44%	47.62%	46.09%	60.71%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 11: The FF5M model extended with the 3-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2473	0.2441	0.0289	0.0957	-0.0621	-0.0528	0.1142	0.1335	0.1785
	(0.2072)	(0.2003)	(0.2031)	(0.1885)	(0.2182)	(0.1875)	(0.1951)	(0.1930)	(0.1942)
Mkt-RF	0.7713***	0.7432***	0.7339***	0.7175***	0.7556***	0.7378***	0.4842***	0.4679***	0.6528***
	(0.0512)	(0.0446)	(0.0443)	(0.0490)	(0.0523)	(0.0434)	(0.0419)	(0.0411)	(0.0430)
SMB	-0.5505***	0.2900***	0.5698***	-0.4235***	0.3169***	0.2374***	-0.5041***	-0.5429***	0.1981**
	(0.1047)	(0.0870)	(0.1002)	(0.0906)	(0.1044)	(0.0882)	(0.0840)	(0.0854)	(0.0897)
HML	0.0775	0.0772	0.0075	0.0423	0.2620*	0.1605	0.0844	0.0685	0.1203
	(0.1272)	(0.1208)	(0.1094)	(0.1327)	(0.1573)	(0.1281)	(0.1374)	(0.1338)	(0.1328)
RMW	-0.2484	-0.1482	-0.1023	-0.1946	-0.1011	-0.1663	-0.2262*	-0.1733	-0.3051**
	(0.1781)	(0.1488)	(0.1463)	(0.1472)	(0.1799)	(0.1414)	(0.1270)	(0.1311)	(0.1216)
CMA	-0.6258***	-0.2111	-0.1459	-0.4435**	-0.5330***	-0.6178***	-0.2933	-0.2350	-0.5651***
	(0.1450)	(0.1558)	(0.1385)	(0.1737)	(0.1838)	(0.1531)	(0.1872)	(0.1813)	(0.1730)
WML	-0.1198*	-0.1183*	-0.1364***	-0.0668	-0.0768	-0.0308	0.0091	0.0097	-0.0599
	(0.0618)	(0.0667)	(0.0526)	(0.0543)	(0.0660)	(0.0521)	(0.0529)	(0.0509)	(0.0560)
YC * D	-0.0920	0.4470	0.1432	-0.0424	-0.0315	-0.1959	-0.3103	-0.2030	0.0325
	(0.4401)	(0.4913)	(0.5559)	(0.4279)	(0.4841)	(0.4368)	(0.4523)	(0.4255)	(0.4406)
YC	-1.3733	-1.4856	-1.7054*	-0.2655	0.4825	-0.7441	0.3078	0.6311	-1.0319
	(0.8928)	(1.1105)	(0.9056)	(1.0137)	(0.9820)	(0.8885)	(0.8565)	(0.8603)	(0.8189)
R^2	66.71%	60.03%	62.14%	63.27%	58.56%	64.76%	48.71%	47.26%	61.49%
Adj. R^2	66.03%	59.21%	61.36%	62.52%	57.71%	64.04%	47.65%	46.18%	60.69%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 12: The FF5M model extended with the 6-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2601	0.2668	0.0579	0.1124	-0.0878	-0.0472	0.1040	0.1099	0.1747
	(0.2057)	(0.1921)	(0.2002)	(0.1865)	(0.2140)	(0.1861)	(0.1947)	(0.1929)	(0.1921)
Mkt-RF	0.7771***	0.7494***	0.7392***	0.7186***	0.7626***	0.7395***	0.4829***	0.4667***	0.6576***
	(0.0519)	(0.0448)	(0.0448)	(0.0482)	(0.0521)	(0.0427)	(0.0422)	(0.0413)	(0.0434)
SMB	-0.5673***	0.2754***	0.5500***	-0.4274***	0.3246***	0.2270***	-0.5025***	-0.5361***	0.1867**
	(0.1035)	(0.0836)	(0.0974)	(0.0896)	(0.1022)	(0.0881)	(0.0833)	(0.0849)	(0.0880)
HML	0.0631	0.0667	-0.0060	0.0386	0.2557	0.1531	0.0847	0.0717	0.1107
	(0.1279)	(0.1218)	(0.1085)	(0.1332)	(0.1565)	(0.1277)	(0.1381)	(0.1345)	(0.1326)
RMW	-0.2636	-0.1565	-0.1172	-0.1971	-0.0963	-0.1769	-0.2279*	-0.1705	-0.3158**
	(0.1781)	(0.1513)	(0.1475)	(0.1481)	(0.1799)	(0.1427)	(0.1278)	(0.1314)	(0.1230)
CMA	-0.6268***	-0.2209	-0.1514	-0.4422**	-0.5292***	-0.6167***	-0.2880	-0.2310	-0.5684***
	(0.1474)	(0.1538)	(0.1364)	(0.1719)	(0.1829)	(0.1512)	(0.1865)	(0.1814)	(0.1710)
WML	-0.1112*	-0.1129*	-0.1286**	-0.0655	-0.0754	-0.0257	0.0096	0.0085	-0.0535
	(0.0618)	(0.0684)	(0.0518)	(0.0544)	(0.0650)	(0.0524)	(0.0531)	(0.0509)	(0.0556)
YC * D	-0.0134	0.6363	0.3363	0.0705	-0.1369	-0.1862	-0.4052	-0.3707	0.0084
	(0.4655)	(0.5732)	(0.5988)	(0.4756)	(0.5035)	(0.4596)	(0.4590)	(0.4303)	(0.4781)
YC	-1.2991	-1.6095*	-1.4587*	-0.3092	-0.8277	-0.4307	0.4298	0.5395	-1.0057
	(0.8922)	(1.0236)	(0.9020)	(0.8687)	(0.9524)	(0.8435)	(0.8330)	(0.8265)	(0.8443)
R^2	66.69%	60.17%	62.07%	63.28%	58.62%	64.71%	48.77%	47.31%	61.48%
Adj. R^2	66.00%	59.35%	61.29%	62.52%	57.77%	63.98%	47.72%	46.23%	60.69%

*** *$p < 0.01$.*
** *$p < 0.05$.*
* *$p < 0.1$.*

Table 103: The FF5M model extended with the 12-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2180	0.1851	0.0126	0.0189	-0.1528	-0.0861	0.0322	0.0330	0.1109
	(0.2032)	(0.1952)	(0.2019)	(0.1913)	(0.2146)	(0.1871)	(0.1932)	(0.1912)	(0.1901)
Mkt-RF	0.7683***	0.7420***	0.7307***	0.7161***	0.7548***	0.7353***	0.4820***	0.4667***	0.6491***
	(0.0513)	(0.0449)	(0.0452)	(0.0490)	(0.0526)	(0.0433)	(0.0412)	(0.0404)	(0.0423)
SMB	-0.5751***	0.2753***	0.5500***	-0.4341***	0.3181***	0.2192**	-0.5119***	-0.5453***	0.1839**
	(0.1058)	(0.0867)	(0.0996)	(0.0905)	(0.1046)	(0.0890)	(0.0831)	(0.0845)	(0.0889)
HML	0.0788	0.0822	0.0058	0.0460	0.2642*	0.1612	0.0850	0.0713	0.1178
	(0.1275)	(0.1199)	(0.1100)	(0.1322)	(0.1564)	(0.1279)	(0.1362)	(0.1327)	(0.1309)
RMW	-0.2655	-0.1623	-0.1205	-0.1992	-0.0968	-0.1772	-0.2264*	-0.1692	-0.3168**
	(0.1767)	(0.1502)	(0.1477)	(0.1491)	(0.1807)	(0.1423)	(0.1271)	(0.1307)	(0.1238)
CMA	-0.6442***	-0.2325	-0.1574	-0.4613***	-0.5437***	-0.6320***	-0.3058*	-0.2491	-0.5773***
	(0.1468)	(0.1536)	(0.1389)	(0.1723)	(0.1819)	(0.1518)	(0.1856)	(0.1806)	(0.1689)
WML	-0.1113*	-0.1131*	-0.1297**	-0.0602	-0.0722	-0.0234	0.0168	0.0162	-0.0511
	(0.0618)	(0.0656)	(0.0543)	(0.0554)	(0.0658)	(0.0526)	(0.0534)	(0.0512)	(0.0564)
YC * D	-0.4013	-0.0071	-0.0496	-0.6230	-0.6617	-0.5111	-0.9275**	-0.9225**	-0.5022
	(0.4424)	(0.5349)	(0.6105)	(0.4286)	(0.4503)	(0.4417)	(0.4857)	(0.4744)	(0.4830)
YC	-0.6133	-0.3128	0.2632	-0.2393	0.5122	-0.4148	0.2656	0.2101	1.0001
	(0.8863)	(1.0622)	(0.7797)	(0.9450)	(1.0487)	(0.8982)	(0.8543)	(0.8565)	(0.8260)
R^2	66.62%	59.67%	61.75%	63.46%	58.74%	64.82%	49.25%	47.80%	61.61%
Adj. R^2	65.93%	58.84%	60.96%	62.71%	57.89%	64.09%	48.21%	46.73%	60.82%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

5. Conclusion

This study examines the impact of the German yield curve inversion on the stock markets of Germany, the Netherlands, and Switzerland, utilizing extended Fama-French Five Factor models. The analysis incorporates various specifications of the yield curve factor, including unlagged and lagged changes, to assess their effect on the stock market returns.

The results of the model extended with unlagged changes in the yield spread indicate that the German yield curve has a significant relationship with stock market performance in Germany and the Netherlands, albeit with varying degrees of impact. The model reveals that changes in the German yield curve positively correlate with excess returns, particularly for the DAX index. This finding supports the hypothesis that the yield curve has a positive relationship with stock returns in Germany. For the Dutch stock market, the AEX and ASCX indices also show positive correlations, suggesting a spillover effect. However, the impact on Swiss indices is insignificant, indicating that other local or global factors might significantly influence these markets. In short, the first hypothesis is partially supported, as positive significant relationships between

The lagged models provide additional insights into the timing of yield curve impacts. The 3-month lag model indicates that changes in the yield curve spread could have delayed negative effects on stock returns, with significant results only for the SDXK index. However, no consistent patterns emerge for longer lags (6, 9, 12, and 24 months), aligning with the findings of Fama and French (2019) that the predictive power of yield curves diminishes over extended periods. These mixed results suggest that while there is some evidence supporting our hypothesis that the German yield curve has a lagged effect on stock market returns in Germany, and the Netherlands, the overall findings are inconclusive.

The inclusion of the interaction term to capture asymmetric effects between yield curve inversions and normal yield curves produces limited statistically significant results. While the large-cap and mid-cap Swiss indices show some significant asymmetric responses at 9- and 12-month lags, the results are not consistent across all indices. This suggests that although there may be differential impacts of yield curve changes during inversion periods, these effects are not uniformly significant across the sample indices. This finding is inconsistent with previous literature, which finds that stock market returns are generally lower in periods preceded by inverted yield curves (McCown, 2001).

The study's findings also highlight some limitations of extending the FF5M with a yield curve factor, as discussed in Chapter 2. While adding the yield curve factor provides some additional explanatory power, the overall improvement is marginal. This aligns with Petkova (2006) and Leite et al. (2020), who suggest that Fama-French factors might already capture much of the information provided by macroeconomic variables like the yield curve. The mixed results, particularly for the Swiss indices, suggest that the yield curve's impact may be more complex and context-dependent than the extended FF5M can fully capture. The ambiguous effects observed highlight the importance of considering local economic conditions and broader global factors when evaluating stock market responses to yield curve movements.

Future research could expand on this study by incorporating additional macroeconomic variables and exploring sector-specific impacts to better understand the dynamics at play. Moreover, investigating the role of central bank policies and investor sentiment during yield curve inversion periods could provide deeper insights into the mechanisms driving these observed relationships.

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7. Appendix

Table 14: The FF5M model extended with the 9-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2722	0.1833	0.0150	0.1082	-0.0555	-0.0096	0.1633	0.1629	0.1857
	(0.1940)	(0.1929)	(0.1968)	(0.1855)	(0.2051)	(0.1802)	(0.1817)	(0.1801)	(0.1781)
Mkt-RF	0.7683***	0.7415***	0.7305***	0.7173***	0.7571***	0.7366***	0.4842***	0.4688***	0.6515***
	(0.0513)	(0.0447)	(0.0448)	(0.0488)	(0.0524)	(0.0428)	(0.0421)	(0.0413)	(0.0428)
SMB	-0.5692***	0.2774***	0.5517***	-0.4290***	0.3203***	0.2225**	-0.5052***	-0.5383***	0.1835**
	(0.1041)	(0.0860)	(0.0989)	(0.0897)	(0.1034)	(0.0883)	(0.0835)	(0.0851)	(0.0876)
HML	0.0741	0.0829	0.0110	0.0378	0.2574**	0.1504	0.0779	0.0644	0.1152
	(0.1280)	(0.1194)	(0.1097)	(0.1334)	(0.1569)	(0.1277)	(0.1376)	(0.1342)	(0.1321)
RMW	-0.2644*	-0.1622	-0.1210	-0.1975	-0.0954	-0.1753	-0.2245*	-0.1673	-0.3161**
	(0.1775)	(0.1502)	(0.1464)	(0.1482)	(0.1788)	(0.1414)	(0.1279)	(0.1317)	(0.1228)
CMA	-0.6300***	-0.2332*	-0.1640	-0.4387***	-0.5228***	-0.6074***	-0.2797**	-0.2232*	-0.5654***
	(0.1454)	(0.1507)	(0.1379)	(0.1725)	(0.1816)	(0.1496)	(0.1864)	(0.1814)	(0.1690)
WML	-0.1147**	-0.1119**	-0.1278***	-0.0678	-0.0815	-0.0316	0.0065	0.0062	-0.0584
	(0.0617)	(0.0656)	(0.0538)	(0.0549)	(0.0653)	(0.0521)	(0.0520)	(0.0502)	(0.0552)
YC	-0.0483	-0.4466	-0.9512	0.7386	1.0831	1.3265*	0.5744	0.4971	0.8309
	(0.8445)	(0.9031)	(0.8360)	(0.7458)	(0.8745)	(0.7635)	(0.7040)	(0.7144)	(0.7097)
R^2	66.50%	59.69%	61.86%	63.34%	58.67%	64.90%	48.68%	47.20%	61.43%
Adj. R^2	65.90%	58.96%	61.18%	62.68%	57.93%	64.27%	47.76%	46.26%	60.74%

*** *$p < 0.01$.*
** *$p < 0.05$.*
* *$p < 0.1$.*

Table 15: The FF5M model extended with the 24-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2741	0.1901	0.0228	0.1112	-0.0486	-0.0097	0.1601	0.1595	0.1793
	(0.1947)	(0.1933)	(0.1965)	(0.1850)	(0.2066)	(0.1815)	(0.1820)	(0.1803)	(0.1797)
Mkt-RF	0.7671***	0.7383***	0.7289***	0.7117***	0.7471***	0.7308***	0.4841***	0.4692***	0.6526***
	(0.0515)	(0.0447)	(0.0453)	(0.0481)	(0.0518)	(0.0432)	(0.0423)	(0.0416)	(0.0428)
SMB	-0.5717***	0.2697***	0.5452***	-0.4377***	0.3041***	0.2155***	-0.5034***	-0.5359***	0.1886**
	(0.1044)	(0.0864)	(0.1000)	(0.0899)	(0.1023)	(0.0883)	(0.0836)	(0.0854)	(0.0877)
HML	0.0743	0.0822	0.0074	0.0432	0.2660**	0.1584	0.0804	0.0665	0.1184
	(0.1273)	(0.1186)	(0.1086)	(0.1311)	(0.1555)	(0.1276)	(0.1377)	(0.1343)	(0.1321)
RMW	-0.2659*	-0.1666	-0.1236	-0.2047	-0.1084	-0.1825	-0.2243*	-0.1666	-0.3142**
	(0.1780)	(0.1505)	(0.1469)	(0.1472)	(0.1778)	(0.1410)	(0.1274)	(0.1310)	(0.1231)
CMA	-0.6315***	-0.2354*	-0.1612	-0.4513***	-0.5440***	-0.6235***	-0.2830**	-0.2254*	-0.5683***
	(0.1452)	(0.1500)	(0.1365)	(0.1703)	(0.1810)	(0.1505)	(0.1870)	(0.1819)	(0.1697)
WML	-0.1142**	-0.1114**	-0.1292***	-0.0633	-0.0739	-0.0255	0.0079	0.0071	-0.0571
	(0.0611)	(0.0660)	(0.0532)	(0.0546)	(0.0655)	(0.0527)	(0.0526)	(0.0507)	(0.0556)
YC	0.2763	0.7864	0.5153	1.1916	2.1675**	1.1530	-0.0652	-0.1558	-0.3923
	(0.8893)	(0.9083)	(0.7833)	(0.7896)	(0.9825)	(0.8046)	(0.7722)	(0.7774)	(0.8323)
R^2	66.51%	59.74%	61.77%	63.46%	59.09%	64.85%	48.61%	47.15%	61.35%
Adj. R^2	65.91%	59.02%	61.09%	62.80%	58.35%	64.21%	47.69%	46.21%	60.66%

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Table 16: The FF5M model extended with the 9-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.2371	0.1986	0.0130	0.0466	-0.1065	-0.0648	0.0437	0.0433	0.1452
	(0.2045)	(0.1946)	(0.2011)	(0.1887)	(0.2127)	(0.1846)	(0.1927)	(0.1910)	(0.1902)
Mkt-RF	0.7680***	0.7416***	0.7304***	0.7168***	0.7567***	0.7361***	0.4832***	0.4678***	0.6511***
	(0.0513)	(0.0449)	(0.0449)	(0.0490)	(0.0528)	(0.0430)	(0.0416)	(0.0408)	(0.0428)
SMB	-0.5696***	0.2776***	0.5517***	-0.4298***	0.3197***	0.2218**	-0.5067***	-0.5398***	0.1830**
	(0.1044)	(0.0861)	(0.0991)	(0.0897)	(0.1035)	(0.0883)	(0.0827)	(0.0843)	(0.0878)
HML	0.0764	0.0819	0.0111	0.0418	0.2607*	0.1539	0.0856	0.0721	0.1178
	(0.1283)	(0.1203)	(0.1105)	(0.1335)	(0.1568)	(0.1278)	(0.1371)	(0.1338)	(0.1323)
RMW	-0.2641	-0.1623	-0.1210	-0.1971	-0.0951	-0.1749	-0.2237*	-0.1665	-0.3159**
	(0.1777)	(0.1505)	(0.1465)	(0.1493)	(0.1796)	(0.1423)	(0.1278)	(0.1315)	(0.1233)
CMA	-0.6350***	-0.2310	-0.1643	-0.4474***	-0.5300***	-0.6152***	-0.2966	-0.2401	-0.5712***
	(0.1464)	(0.1534)	(0.1401)	(0.1733)	(0.1828)	(0.1505)	(0.1860)	(0.1810)	(0.1699)
WML	-0.1129*	-0.1127*	-0.1277**	-0.0647	-0.0789	-0.0288	0.0126	0.0123	-0.0564
	(0.0620)	(0.0654)	(0.0544)	(0.0554)	(0.0655)	(0.0523)	(0.0528)	(0.0506)	(0.0557)
YC * D	-0.2510	0.1094	-0.0148	-0.4400	-0.3651	-0.3952	-0.8555*	-0.8552*	-0.2897
	(0.4677)	(0.5513)	(0.6147)	(0.4532)	(0.4977)	(0.4695)	(0.4839)	(0.4566)	(0.4880)
YC	-0.0204	-0.4588	-0.9496	0.7875	1.1237	1.3704*	0.6695	0.5921	0.8631
	(0.8483)	(0.9010)	(0.8401)	(0.7515)	(0.8793)	(0.7679)	(0.6988)	(0.7106)	(0.7144)
R^2	66.53%	59.69%	61.86%	63.43%	58.73%	64.98%	49.22%	47.77%	61.48%
Adj. R^2	65.84%	58.86%	61.08%	62.68%	57.88%	64.26%	48.18%	46.69%	60.69%

*** *$p < 0.01$.*
** *$p < 0.05$.*
* *$p < 0.1$.*

Table 17: The FF5M model extended with the 24-month lagged yield curve factor and the interaction term. Mkt-RF, SMB, HML, RMW, and CMA are the factors from Fama-French (2015) 5-factor model and WML is Carhart's (1997) momentum factor. D equals 1 when the yield spread is negative and 0 if otherwise. YC is the change in German yield spread. The numbers between brackets are White's (1980) robust standard errors.

	Germany			**The Netherlands**			**Switzerland**		
	DAX	**MDAX**	**SDXK**	**AEX**	**AMX**	**ASCX**	**SMI**	**SMIM**	**SMCI**
Constant	0.3025	0.0725	0.2207	0.0801	-0.1307	-0.0138	0.1748	0.1745	0.2312
	(0.2011)	(0.2037)	(0.2022)	(0.1964)	(0.2200)	(0.1914)	(0.1913)	(0.1894)	(0.1885)
Mkt-RF	0.7685***	0.7313***	0.7399***	0.7102***	0.7429***	0.7306***	0.4848***	0.4699***	0.6552***
	(0.0511)	(0.0448)	(0.0445)	(0.0478)	(0.0513)	(0.0429)	(0.0420)	(0.0413)	(0.0426)
SMB	-0.5699***	0.5484***	0.2716***	-0.4397***	0.2988***	0.2152**	-0.5025***	-0.5350***	0.1920**
	(0.1047)	(0.0990)	(0.0865)	(0.0900)	(0.1023)	(0.0889)	(0.0838)	(0.0854)	(0.0879)
HML	0.0732	0.0056	0.0810	0.0444	0.2692*	0.1585	0.0799	0.0659	0.1164
	(0.1274)	(0.1089)	(0.1188)	(0.1310)	(0.1545)	(0.1277)	(0.1381)	(0.1347)	(0.1327)
RMW	-0.2637	-0.1196	-0.1642	-0.2072	-0.1150	-0.1829	-0.2232*	-0.1654	-0.3101**
	(0.1784)	(0.1473)	(0.1504)	(0.1474)	(0.1782)	(0.1413)	(0.1278)	(0.1314)	(0.1231)
CMA	-0.6279***	-0.1549	-0.2315	-0.4553***	-0.5544***	-0.6240***	-0.2811	-0.2235	-0.5617***
	(0.1447)	(0.1363)	(0.1502)	(0.1702)	(0.1798)	(0.1506)	(0.1879)	(0.1827)	(0.1708)
WML	-0.1145*	-0.1297**	-0.1117*	-0.0630	-0.0730	-0.0255	0.0078	0.0070	-0.0576
	(0.0612)	(0.0534)	(0.0660)	(0.0546)	(0.0652)	(0.0527)	(0.0528)	(0.0509)	(0.0558)
YC * D	0.2144	0.3751	0.2311	-0.2345	-0.6194*	-0.0313	0.1111	0.1134	0.3917
	(0.4739)	(0.4532)	(0.4504)	(0.3687)	(0.3652)	(0.3703)	(0.4974)	(0.5212)	(0.3957)
YC	0.2467	0.4635	0.7544	1.2240	2.2530**	1.1574	-0.0806	-0.1714	-0.4464
	(0.8990)	(0.7797)	(0.9152)	(0.7955)	(0.9854)	(0.8048)	(0.7663)	(0.7696)	(0.8320)
R^2	66.53%	59.77%	61.84%	63.49%	59.25%	64.85%	48.62%	47.16%	61.44%
Adj. R^2	65.84%	58.94%	61.06%	62.73%	58.41%	64.12%	47.57%	46.08%	60.64%

**** $p < 0.01$.*
*** $p < 0.05$.*
** $p < 0.1$.*