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The power of the yield curve prediction:

An analysis of the yield curve prediction for recessions in the Eurozone between 2004 and 2024

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Abstract

This dissertation examines the predictive power of the yield curve (10Y-3M spread triple-A rated government bonds) as a leading indicator of recessions in the Eurozone in the period 2004-2024. In the economic literature, an inverted yield curve is considered a reliable signal of impending recessions but the monetary policy interventions of the European Central Bank (ECB) after the 2008 financial crisis may have distorted this relationship. Probit models are used to analyze whether the 10Y-3M spread continues to have significant predictive power for recessions and to what extent macroeconomic indicators such as inflation (HICP) and economic growth (GDP growth) influence this effect. The results show that the spread continues to act as a leading indicator for recessions, but that its predictive power was weakened after 2008. In addition, the analysis shows that strong economic growth reduces the predictive power of the spread, while high inflation strengthens this effect. Robustness tests, including a logit model, time lags (t-3, t-6), an AUC-ROC and McFadden R^2 test, confirm that while the yield curve remains a useful indicator, it should no longer be considered in isolation. The results have far-reaching implications for monetary policy and financial markets: the ECB should take greater account of alternative indicators such as labor market and credit market data, while investors should include additional macroeconomic factors in their recession forecasts.

Keywords: yield curve, forecast, recession, Europe, macroeconomics

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Resumo

Esta dissertação examina o poder preditivo da curva de rendimentos (spread 10Y-3M das obrigações do tesouro com notação triplo A) como indicador avançado de recessões na zona euro no período 2004-2024. Na literatura económica, uma curva de rendimentos invertida é considerada um sinal fiável de recessões iminentes, mas as intervenções de política monetária do Banco Central Europeu (BCE) após a crise financeira de 2008 podem ter distorcido esta relação. É utilizado um modelo probit para analisar se o diferencial 10Y-3M continua a ter um poder preditivo significativo para as recessões e em que medida as variáveis macroeconómicas, como a inflação (IHPC) e o crescimento económico (crescimento do PIB), influenciam este efeito. Os resultados mostram que o diferencial continua a atuar como um indicador avançado de recessões, mas que o seu poder de previsão foi enfraquecido após 2008. Além disso, a análise mostra que um forte crescimento económico reduz o poder de previsão do diferencial, enquanto uma inflação elevada reforça este efeito. Os testes de robustez, incluindo um modelo logit, desfasamentos temporais (t-3, t-6), um teste AUC-ROC e McFadden R^2, confirmam que, embora a curva de rendimentos continue a ser um indicador útil, já não deve ser considerada isoladamente. Os resultados têm implicações de grande alcance para a política monetária e os mercados financeiros: o BCE deve ter mais em conta indicadores alternativos, como os dados do mercado de trabalho e do mercado de crédito, enquanto os investidores devem incluir variáveis macroeconómicas adicionais nas suas previsões de recessão.

Palavras-chave: curva de rendimentos, previsão, recessão, Europa, macroeconomia

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Table of Contents

List of Abbreviation

Expectations Hypothesis	EH
European Central Bank	ECB
United States Federal Reserve	Fed
Quantitative Easing	QE
Long-Term Refinancing Operation	LTRO
United States (of America)	US
Gross Domestic Product	GDP
Harmonized Index of Consumer Prices	HICP
Organisation for Economic Co-operation and Development	OECD
Federal Reserve Bank of St. Louis	FRED
Generalized Linear Model	GLM
Linear Probability Model	LPM
Cumulative Distribution Function	CDF
Area Under the Curve	AUC
Receiver Operating Characteristic	ROC

List of Tables

List of Figures

1. Introduction

From a perspective in 2025, if we reflect on the past years in the Eurozone, we can for sure say that we live in a challenging and fast-paced environment: The financial crisis which changed perspectives about the role of financial institutions, the Euro crisis heating up debates about the European Union, the COVID-19 pandemic which made the world stand still as well as the latest war in the Ukraine which has complex consequences in many dimensions. This list should give an indication of what socio-economic and geopolitical challenges we faced in this century. The recessions that came with those events had to be countered by policymakers in order to make the economy grow again.

Subsequently, the prediction of recessions is a central challenge in macroeconomics. Reliable early indicators are needed for agents in financial markets, central banks and political decision makers in order to detect economic crises and take action. One of the most discussed indicators for economy cycles is the yield curve. Many empirical studies showed that an inverted yield curve, in which the yield of the shorter-termed bond is above the yield of longer-termed bond, has had an enormous prediction power in the past for recessions (Estrella & Mishkin, 1998; Bauer & Mertens, 2018a).

The theoretical justification is mainly based on two central explanations: Firstly, the expectations hypothesis (EH) of the term structure of interest rates reflects the fact that long-term interest rates contain the aggregate expectations of market participants about future short-term interest rates (Fama, 1984). If short-term interest rates rise because the central bank is adjusting its monetary policy, for example, while long-term interest rates stagnate or fall, this indicates that the market is expecting a future economic slowdown. Secondly, the term structure of interest rates is influenced by the liquidity preference theory (Keynes, 1936), which suggests that investors generally demand a risk premium for long-term bonds, which means that long-term interest rates are usually higher than short-term interest rates. An inversion of this structure therefore signals unusual market sentiment and can be interpreted as a warning signal of an impending recession (Rudebusch & Williams, 2009).

While this relationship between an inverted yield curve and subsequent recessions is well examined in the US (Estrella & Mishkin, 1996; Wright, 2006), the situation in the Eurozone is less clear. One of the main reasons for this lies in the different economic structures and monetary policy frameworks. The European Central Bank (ECB) pursues a monetary policy strategy that differs from that of the United States Federal Reserve (Fed), especially since the

financial crisis of 2008. By introducing unconventional measures such as a negative interest rate policy, quantitative easing (QE) and long-term refinancing operations (LTROs), the ECB has actively influenced long-term interest rates, in order to stabilize financial markets (Claeys et al., 2018). Therefore, the ECB may have altered market signals through its monetary policy interventions, particularly through direct market interventions and bond purchase programs (Draghi, 2014). These measures had a profound impact on the interest rate structure and may have distorted the traditional interpretation of the yield curve as an indicator of recession (Holston, Laubach & Williams, 2017).

In addition, there are structural differences between the US and Eurozone financial markets that could influence the predictive power of the interest rate structure. While the US Treasury market is considered deep and homogeneous, in the Eurozone there are large differences between the yields of government bonds from different member states: Countries such as Germany and the Netherlands enjoy triple-A credit ratings, while others, such as Italy and Greece, have higher yields due to increased credit risks. As a result, the yield spread for triple-A-rated government bonds in the Eurozone may not send the same macroeconomic signals as in the US (Holston, Laubach & Williams, 2017).

Some recent studies have also questioned whether the yield curve remains a reliable leading indicator of recessions in the modern monetary policy landscape. While it worked well in the past, authors such as Cooper et al. (2020) argue that increasing market intervention by central banks, especially after the financial crisis, may have reduced the informational efficiency of the yield curve.

In this context, the key question for my dissertation is whether the yield curve remains a reliable leading indicator for recessions in the Eurozone or whether it has lost its significance in its power due to monetary policy distortions. If the monetary policy did alter the prediction power of the yield curve, it is of interest to examine alternative macroeconomic indicators (such as GDP growth and inflation) and their influence on the yield curve prediction, possibly influencing its prediction power. In consideration of the latest economic challenges, including the COVID-19 crisis, the increased inflation from 2021 and the energy crisis in the wake of the war in Ukraine, a reassessment of the predictive power of the yield curve is urgently needed in the Eurozone. Especially because the outcome of the war in Ukraine is uncertain and the resulting consequences for Europe in political and economic terms are unpredictable.

The empirical analysis of my research question is based on an analysis of time series data for the Eurozone in the period 2004-2024, examining whether the 10Y-3M yield spread for triple-A rated government bonds has proven to be a reliable leading indicator of recessions (derived from OECD evidence) in the past or whether its predictive value has been significantly weakened by the ECB's monetary policy measures after the financial crisis. In addition, it is examined whether additional macroeconomic indicators such as GDP growth and the inflation rate (represented by the Harmonized Index of Consumer Prices, HICP) have an impact on the predictive power of the yield curve. Probit regressions will show the statistical model of the recession probabilities in dependance on the yield spread and other macroeconomic variables, while I will also assess the period pre financial crisis in comparison with the period post financial crisis. The impact of the macroeconomic variables will be tested by comparing the model outcome with and without the macroeconomic control variables as well as their respective interaction. The robustness will be ensured by estimating an alternative logit model, testing alternative time-lags and model performance assessments. The results of this analysis should provide both theoretical insights into the function of the yield curve as an indicator for the Eurozone and derive practical implications for financial markets and monetary policy (Cooper et al., 2020).

This dissertation is structured in six chapters, in which this introduction is followed by a chapter on the theoretical background and literature about the function of the yield curve as well as its role as a forecasting tool. Chapter three will cover the method including a presentation of the used data and variables, the econometric model and the robustness tests. Followed by the empirical analysis and an in-depth look on the obtained results. After this, I will dedicate a chapter on the interpretation of the results, its limitations as well as its implications for monetary policy and finishing my dissertation with a conclusion, which will summarize all results and give an outlook.

2. Theoretical Background & Literature

The yield curve describes the relationship between the terms to maturity and the yield of fixed-interest securities with the same credit rating, in particular government bonds. It serves as an indicator of market participants' expectations regarding future interest rates, inflation and economic development (Deutsche Bundesbank, 2023). The yield curve is a key tool for agents in the financial market, economists and central banks to analyze the macro-financial context and economic dynamics (Bauer & Mertens, 2018a).

The shape of the yield curve can be steep, flat or inverted, with each of these structures reflecting different economic conditions (Fama, 1984):

- A steep yield curve implies that long-term returns are higher than short-term returns, as investors demand a risk premium for tying up capital for longer. This usually indicates economic growth and rising inflation expectations.
- On the other hand, a flat yield curve occurs when short-term and long-term interest rates converge, which can be a sign of economic uncertainty. A flat interest rate structure can indicate that the economy is approaching a turning point (Bauer & Mertens, 2018a).
- When short-term interest rates are higher than long-term rates, this is referred to as an inverted yield curve. This means that the difference between the yields is negative. An inverted yield curve is often seen as an early indicator of an impending recession, as it points to a restrictive monetary policy (Estrella & Mishkin, 1998).

There are several theoretical explanations for how the yield curve works and what the implications are. Some of the most important are the expectations hypothesis of the term structure of interest rates, the liquidity preference theory and the segmented markets theory.

The expectations hypothesis states that long-term interest rates are determined by expected future short-term interest rates. Accordingly, the yield on long-term bonds corresponds to the average expected short-term interest rate over the term of the bond. It assumes that investors have no systematic preference for specific maturities and that long-term interest rates therefore merely reflect expected future interest rates (Fama, 1984).

If market participants expect short-term interest rates to fall, long-term interest rates will also fall, which can lead to an inverted yield curve (Campbell & Shiller, 1991). This expectation

hypothesis thus explains some of the observed changes in the yield curve, but is often criticized as being too simplistic, as it does not take risk premiums or market segmentation into account (Rudebusch & Williams, 2009).

The liquidity preference theory (Keynes, 1936) expands on the expectation hypothesis by taking into account the assumption that investors demand a higher premium for long-term investments. Long-term investments are associated with higher uncertainties and lower liquidity. To compensate for these risks, investors demand a risk premium, which is why long-term interest rates are usually higher than short-term interest rates (Campbell & Shiller, 1991).

An inverted yield curve therefore only arises if market participants expect future short-term interest rates to fall sharply and this expectation is so strong that it exceeds even the long-term risk premium (Bauer & Mertens, 2018a).

The segmented market theory, in contrast, postulates that the bond market is divided into independent segments, each of which is dominated by specific investors (Modigliani & Sutch, 1966). Pension funds, for example, prefer long-term bonds, while commercial banks tend to invest in short-term investments. This segmentation means that supply and demand within individual maturity segments influence interest rates, regardless of the expectation of future interest rate developments (Modigliani & Sutch, 1966).

In this model, an inverted yield curve can arise if there is a strong excess demand in the long-term segment - for example due to central bank interventions such as QE for example, which artificially lower long-term interest rates (Claeys et al., 2018).

While the whole topic of forecasting the economic future is a topic of interest for many economists, a large number of empirical studies show and prove that an inverted yield curve is a reliable indicator of economic declines. Estrella & Mishkin (1998) found that an inversion of the yield curve in the US has correctly predicted almost every recession since the 1960s. More recent studies also confirm this forecasting power (Bauer & Mertens, 2018a). As Bauer and Mertens (2018b) indicate, the spread between 10Y and 2Y bonds is often examined for these forecasts by financial commentators, while the spread between 10Y and 3M is of interest in most of the academic literature including Estrella and Mishkin (1998). I will be therefore focusing on the spread between 10Y and 3M to be in line with the academic tradition.

In the Eurozone, the ECB has used unconventional monetary policy measures such as QE to stimulate the economy since the 2008 financial crisis. These measures influence long-term

interest rates and could change the significance of the yield curve as an indicator of recession. A study by the Deutsche Bundesbank (2013) examines how well a recession can be predicted on the basis of yield curves and analyzes the influence of monetary policy measures on this forecasting ability after the financial crisis.

The explanation for the predictive power of yield curves after the financial crisis lies in the fact that an inverse interest rate structure is often associated with a restrictive monetary policy and a slowdown in lending. If the central bank raises short-term interest rates to counter inflation, lending costs for companies and households can rise, which harms economic activity and ultimately leads to a recession (Wright, 2006).

However, there is also criticism of the use of the yield curve as the sole leading indicator. Some authors argue that after the financial crisis, the unconventional monetary policy measures artificially lowered long-term interest rates, thereby limiting the informative value of the yield curve (Cooper et al., 2020).

Some recent studies therefore suggest that the yield curve should be combined with other macroeconomic indicators in order to achieve more reliable predictive power (Cooper et al., 2020).

As there is no definite consensus about the magnitude of the role of monetary policy in the predictive power of the yield curve (Cooper et al., 2020), with Wright (2006) and Bauer and Mertens (2018a) standing on opposite sides exemplarily, it is important to conduct this analysis for a recent one in the Eurozone. Especially taking into account its differences in structure (Holston, Laubach & Williams, 2017) and macroeconomic policy (Claeys et al., 2018) compared to the US. Other studies with focus on the yield curve prediction in the Eurozone specify on its performance drivers (Sabes & Sahuc, 2023), other time periods like 1970 – 2000 (Duarte et al., 2005) or augmented models tested with non-monetary policy variables such as a composite European stock price index (Gogas et al., 2009). Other studies also compare the predictive power of the yield curve internationally (Chinn & Kucko, 2015).

My focus will be on the examination of the role of ECB's monetary policy after the financial crisis affecting the prediction power, the influence of macroeconomics indicators and of course the practical implications of my results for all relevant stakeholders.

3. Method

3.1. Data

The empirical analysis of this dissertation is based on a combination of macroeconomic time series data and financial market data for the period September 2004 to December 2024. The data set includes yield curve spot rates at different maturities and its spread, macroeconomic indicators and a recession indicator from renowned sources such as the ECB, the OECD and the Federal Reserve Bank of St. Louis (FRED).

The multiple economic datasets that are used to analyze the predictive power of the yield curve for recessions in the Eurozone, come from the following sources:

- The yield curve spot rates for 10Y- and 3M maturity government bonds which are triple-A rated in the Eurozone, including its spread, are obtained from the ECB Data Portal. Because the higher rated government bonds are more stable, as a high rating implies, they are well suited for this analysis. The data was available on a daily basis (business week) but was aggregated to a monthly average for the regressions. This data was crucial as the yield curve is a key indicator for market participants' expectations regarding future economic cycles (Estrella & Mishkin, 1998; Bauer & Mertens, 2018a).

- The macroeconomic indicators that I included additionally are inflation (represented by the HICP) and the GDP growth, both for the Eurozone. Both data sets were obtained from the ECB Data Portal as well. While the frequency of the HICP data was already monthly, the given frequency of the GDP growth rate data was on a quarterly basis – I interpolated it into monthly data. While inflation influences the monetary policy of central banks and can therefore indirectly change the yield curve (Holston, Laubach & Williams, 2017), the GDP growth as well is an extremely important indicator reflecting economic growth as a whole.

- The indicator for recession was obtained from the FRED, which made a time series which is an interpretation from the OECD "Composite Leading Indicators: Reference Turning Points and Component Series" data. The dataset is binary, therefore reflects on a monthly basis whether there was a recession in the Eurozone or not. Unfortunately, the data was only available until the 31st of August 2022. Therefore, we filled in the missing values for our researched period by forward filling. As we analyse the

prediction power for recessions, it is important to include a quantified distinction, when we had a recession within our examined period.

The used variables for this analysis can be divided into three main categories: Yield curve, macroeconomic control variables and the recession indicator.

- The yield curve is the central element of this analysis and is represented by the 10Y-3M spread, the difference between the yield on 10-year and 3-month Eurozone government bonds with a triple-A rating. An inverted yield curve, where this spread becomes negative, is interpreted as a potential signal of an impending recession (Estrella & Trubin, 2006). Long-term interest rates are influenced in particular by inflation expectations and central bank measures, while short-term interest rates are determined to a greater extent by monetary policy decisions (Rudebusch & Williams, 2009).

- The macroeconomic control variables, include inflation and GDP growth. Rising inflation can prompt the central bank to raise interest rates, which could cause short-term interest rates to rise and the yield curve to flatten (Bauer & Mertens, 2018a). GDP decline on the other hand is a form of economic decline and could influence yields.

- The recession indicator is the dependent variable, which shows if we face a recession in the Eurozone (1= recession, 0= no recession).

As the original data had different frequencies (daily yield curve data, monthly inflation data/recession indicator data, quarterly GDP growth data), the data was adjusted (aggregated averages, interpolated and forward filled where needed respectively) and harmonized. We now look at 244 months, between September 2004 and December 2024, for all the variables described on a monthly basis.

3.2. Econometric Model

The goal of the analysis in this dissertation is to assess the predictive power of the yield curve for recessions in the Eurozone. For this reason, a probit regression model is used to model the probability of a recession on the basis of the yield curve and macroeconomic indicators. The choice of this method is based on the fact that the dependent variable, the OECD-based recession indicator, is a binary variable (1 = recession, 0 = no recession), meaning that classic linear models such as OLS regression would be unsuitable (Wright, 2006).

A probit regression is a special form of the generalized linear model (GLM) and is suitable for modelling binary dependent variables, as in our model. In contrast to the linear probability model (LPM), probit regression ensures that the predicted probabilities remain in the interval [0,1] by using a cumulative distribution function (CDF) for modeling (Maddala, 1983). The use of a probit regression is also the standard practice to evaluate the probability of an incoming regression (Bauer & Mertens, 2018a).

Therefore, we estimate the following probit regression:

$$P(Recession_t = 1) = \Phi(\beta_0 + \beta_1 Spread_{t-1} + \beta_2 GDPgrowth_{t-1} + \beta_3 HICP_{t-1} + \epsilon_t) \quad (1)$$

Where $Recession_t$ is the dependent dummy variable that takes the value one if there is a recession in month t, Φ is the standard normal cumulative distribution function, β_0 denotes the intercept, β_1 is the coefficient for the 10Y-3M yield spread (our main independent variable), β_2 is the coefficient for GDP growth, β_3 is the coefficient for inflation (represented by the HICP) and ϵ_t denotes the error term. When $\beta > 0$, an increase of the variables increases the probability of a recession and vice versa when $\beta < 0$. As economic developments occur with a time lag, the explanatory variables are included in the model with a lag structure (t - 1 month). This ensures that the explanation of the recession is based on past values and not on simultaneous or lagged variations (Bauer & Mertens, 2018a).

The hypotheses of the study can be operationalized and tested with multiple methods. The first hypothesis, that an inverted yield curve is a reliable indicator for recession, can be tested by estimating the β_1 significance in the probit regression. Secondly, that the prediction power of the yield curve has changed after the financial crisis because of ECB's monetary policy, can be tested by comparing the coefficients for the period 2004 – 2008 as well as 2009 – 2024. For doing so, we added a spread interaction variable between the spread and the post-2008 time period. Therefore, we estimated:

$$P(Recession_t = 1) = \Phi(\beta_0 + \beta_1 Spread_{t-1} + \beta_2 SpreadInteraction_{t-1} + \beta_3 GDPgrowth_{t-1} + \beta_4 HICP_{t-1} + \epsilon_t) \quad (2)$$

With β_2 being the coefficient for the spread interaction variable.

The last hypothesis, other macroeconomic factors (GDP growth and inflation) overshadowing or influencing the predictive power of the yield curve, will be assessed by comparing the model with and without the macroeconomic control variables as well as the interaction between the spread and those variables. For the comparison with (1), we therefore estimated a "baseline" probit regression:

$$P(Recession_t = 1) = \Phi(\beta_0 + \beta_1 Spread_{t-1} + \epsilon_t) \quad (3)$$

And also, an interaction probit regression, reflecting the interaction between the macroeconomic variables and the spread:

$$P(Recession_t = 1)$$

$$= \Phi(\beta_0 + \beta_1 Spread_{t-1} + \beta_2 GDPgrowth_{t-1} + \beta_3 HICP_{t-1} + \beta_4 SpreadGDPInteraction_{t-1} + \beta_5 SpreadHICPInteraction_{t-1} + \epsilon_t) \quad (4)$$

With β_4 as the coefficient for the interaction variable between spread and GDP growth and β_5 being the interaction variable between spread and HICP.

3.3. Robustness

The following robustness tests are carried out to ensure the stability of the results:

- A logit model will be estimated as an alternative to the probit regressions. The difference between them is that while the probit model uses the cumulative normal distribution, the logit model is based on the logistic distribution (Greene, 2012). We therefore estimate the following:

$$P(Recession_t = 1) = \frac{e^{\beta_0+\beta_1 Spread_{t-1}+\beta_2 GDPgrowth_{t-1}+\beta_3 HICP_{t-1}+\beta_4 SpreadGDPInteraction_{t-1}+\beta_5 SpreadHICPInteraction_{t-1}}}{1 + e^{\beta_0+\beta_1 Spread_{t-1}+\beta_2 GDPgrowth_{t-1}+\beta_3 HICP_{t-1}+\beta_4 SpreadGDPInteraction_{t-1}+\beta_5 SpreadHICPInteraction_{t-1}}} \quad (5)$$

With the coefficients and variables being similar to the ones we used for the probit model in equation (4). If the results of the probit and logit regressions differ significantly, this could indicate a model-dependent bias.

- Another robustness criterion is the choice of the optimal lag structure. While most studies use a lag of one month (t - 1) (Estrella & Mishkin, 1998), alternative time lags will be tested as well for the probit estimated in (1). Therefore, we estimate:

$$P(Recession_t = 1) = \Phi(\beta_0 + \beta_1 Spread_{t-3} + \beta_2 GDPgrowth_{t-1} + \beta_3 HICP_{t-1} + \epsilon_t) \quad (6)$$

As well as:

$$P(Recession_t = 1) = \Phi(\beta_0 + \beta_1 Spread_{t-6} + \beta_2 GDPgrowth_{t-1} + \beta_3 HICP_{t-1} + \epsilon_t) \quad (7)$$

A time lag of three months (t - 3) would imply mid-term signals, while a time lag of six months (t - 6) implies long-term signals for predictive power, depending on the significance. The latter would be given if the forecasting power improves with longer lags, indicating that changes in the interest rate structure provide very early recession signals.

- In order to evaluate the model performance, we look at the Receiver Operating Characteristic (ROC) curve and use the Area Under the Curve (AUC) score, which will measure how well the model distinguishes between recession and non-recession.

$$AUC = \int_0^1 ROC(x)dx \quad (8)$$

Where $ROC(x)$ is the ROC curve function with x as the respective threshold value. The ROC curve is the plot of:

The $TPR\ (True\ Positive\ Rate) = \frac{True\ Positives}{True\ Positives + False\ Negatives}$

Against the $FPR\ (False\ Positive\ Rate) = \frac{False\ Positives}{False\ Positives + True\ Negatives}$

An AUC value of 1.0 would mean perfect classification, while 0.5 would be a random classification.

- Additionally, McFadden's R^2 will be used to measure the explained variance for binary models (Maddala, 1983):

$$R^2_{McFadden} = 1 - \frac{\ln(L_{Model})}{\ln(L_{Zero})} \qquad (9)$$

With $L_{Model} = Likelihood\ of\ the\ estimated\ model$

And $L_{Zero} = Likelihood\ of\ the\ model\ with\ only\ with\ intercept$

Where a higher value indicates a better suitability.

4. Empirical Analysis & Results

4.1. Descriptive Statistics

This chapter conducts an empirical analysis on the predictive power of the yield curve for recessions in the Eurozone. First, a descriptive analysis of the variables will be conducted in order to illustrate their development and possible correlations. Probit models are then estimated to assess whether the 10Y-3M spread acts as a leading predictor for recessions, before and after the financial crisis, and the possible influence of macroeconomic control variables. In addition, further robustness checks are carried out to ensure the stability of the results.

As described in chapter 3, the empirical analysis is based on monthly data for the period September 2004 to December 2024. The variables include the yield curve (10Y-3M spread, 10Y & 3M bond yields), macroeconomic control variables (GDP growth, inflation/HICP) and the OECD-based recession indicator (binary variable: 1 = recession, 0 = no recession).

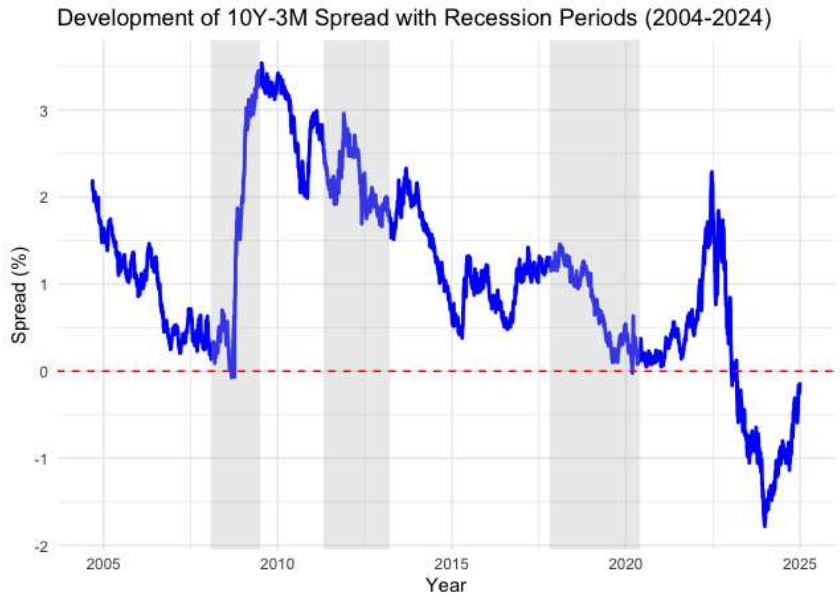

Figure 1: Development of Yield Spread with Recession (2004-2008), daily frequency

Figure 1 shows the development of the 10Y-3M yield spread in the Eurozone within the examined period 2004-2024 on a daily base, with gray bars marking the quantified recession periods. The blue line represents the difference between the yields on 10-year and 3-month

government bonds. The red dashed line highlights the zero line, which is considered the critical threshold for interpreting the yield curve.

An initial observation is that in several cases, the subsistent decrease of the yield spread or the crossing of the red zero line into negative territory, coincides with a current/subsequent recession. This suggests that an inverted yield curve could be a reliable leading indicator of economic downturns, as it indicates that market participants expect monetary policy to be loosened and the economy to weaken. On the other hand, it can be deducted that a sustained positive spread indicates stable economic expansion. To put the period into perspective, it is observable that the yield curve did not only decrease significantly or invert before a recession, but also prior to events that had a socio-economic impact not classified as a recession (e.g. the COVID-19 pandemic). The latest developments (2022-2024) can be placed in the context of the ECB's monetary policy decisions and geopolitical and economic uncertainties. These patterns support the hypothesis that an inverted yield curve is an early indicator of economic downturns (Estrella & Mishkin, 1998; Duarte et al., 2005).

For the conduction of the descriptive analysis, Table 1 shows the statistical key figures for all core variables on a monthly basis (2004-2024). The most important findings include the spread varying widely over time, with episodes of inverted yield curves potentially serving as leading indicators of recessions.

Descriptive Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Spread_10Y_3M	244	1.099	1.058	-1.566	3.418
Yield_10Y	244	1.952	1.587	-0.588	4.667
Yield_3M	244	0.853	1.635	-0.857	4.251
GDP_Growth	244	1.251	2.889	-14.000	15.300
Recession	244	0.291	0.455	0	1
HICP	244	2.134	2.018	-0.600	10.600

Table 1: Descriptive Statistics of all Variables

From the separate yield rates, it is also observable that long-term yields are more stable, while short-term yield rates react more severely to the ECB's monetary policy decisions. The high volatility of GDP growth shows strong economic cycles - especially in times of crisis.

Interestingly, inflation remained close to the ECB target (close to 2%) on average but showed strong fluctuations in times of crisis. These values provide an initial indication of how macroeconomic factors relate to the interest rate structure.

Correlation Matrix

	Spread_10Y_3M	Yield_10Y	Yield_3M	GDP_Growth	Recession	HICP
Spread_10Y_3M	1	0.287	-0.369	-0.150	-0.172	-0.159
Yield_10Y	0.287	1	0.785	-0.060	-0.053	0.188
Yield_3M	-0.369	0.785	1	0.039	-0.163	0.285
GDP_Growth	-0.150	-0.060	0.039	1	-0.239	0.332
Recession	-0.172	-0.053	-0.163	-0.239	1	-0.054
HICP	-0.159	0.188	0.285	0.332	-0.054	1

Table 2: Correlation Matrix of all Variables

Table 2 shows the statistical relationships between the variables in the data set. Values close to +1 or -1 indicate a strong positive or negative correlation, while values close to 0 indicate no significant correlation. The yield spread has a weak negative correlation with recession – while the 10Y maturity yield is almost not correlated at all with recession. Rising inflation correlates slightly with a falling spread - this could be due to monetary policy measures to combat inflation by increasing short-term interest rates. The positive correlation between GDP growth and HICP is also an indicator that economic expansion is tied to inflation. On the other hand, inflation seems not to have a strong relationship with the probability of recession - this could indicate that inflation alone is not a sufficient indicator of economic downturns.

4.2. Results

The probit regression is a non-linear binary regression model that is often used in economic research to model the probability of an event (Wooldridge, 2019). In the case of this dissertation, the extent to which the 10Y-3M yield spread and macroeconomic indicators can predict the probability of a recession in the Eurozone is examined. In a linear regression model, binary dependent variables could be problematic as they can lead to predictions outside the value range of 0 to 1 (Wooldridge, 2019). Probit regressions solve this problem by using a cumulative normal distribution function (Greene, 2012).

The dependent variable in this analysis is the OECD-based recession indicator, which contains a binary classification for each month:

$$Recession_t = \begin{cases} 1, if\ in\ month\ t\ occurs\ a\ recession \\ 0, if\ in\ month\ t\ no\ recession\ occurs \end{cases}$$

The regression models test three central hypotheses:

I. An inverted yield curve significantly increases the probability of recession.

II. The predictive power of the spread changed after the 2008 financial crisis due to the monetary policy of the ECB.

III. Macroeconomic factors (GDP growth & inflation) influence the predictive power of the yield curve.

Probit Regression Result

	Dependent variable:
	Recession
Spread_10Y_3M	-0.190**
	(0.084)
GDP_Growth	-0.117***
	(0.036)
HICP	0.036
	(0.046)
Intercept	-0.731***
	(0.170)
Observations	244
Log Likelihood	-137.200
Akaike Inf. Crit.	282.399
Note:	*p**p***p<0.01

Table 3: Probit Regression Result

Table 3 shows us the probit regression results for our main model, estimated in equation (1). The coefficient value for the intercept (-0.731) shows the base probability of a recession when all independent variables are equal to 0, which is highly significant with its p-value. It is also observable that a lower (negative) spread increases the probability of recession - also with a statistical significance, which confirms the correlation between an inverted yield curve and recession. This allows the deduction: the flatter or more inverted the yield curve, the greater the probability of a recession. The GDP growth coefficient confirms the a priori intuition, that higher economic growth reduces the probability of recession. On the other hand, there was no significance for the HICP, which implies that there is no strong connection between inflation and recession.

The marginal effects in table 7 (see Appendix) indicate that a decrease in the spread by 1 percentage point increases the probability of a recession by 6.04 percentage points and confirms the statistical significance. From an economic standpoint it could mean that a flattening of the interest rate structure could be caused by monetary policy tightening or market expectations of an economic slowdown, which is consistent with empirical studies for the US and the Eurozone (Estrella & Mishkin, 1998; Chinn & Kucko, 2015). The high significance of the GDP growth was also underlined, and it can be thus interpreted that recessions become visible earlier due to a slowdown in GDP growth. An increase in inflation of 1 percentage point increases the probability of recession by only 1.15 percentage points, but the effect is not significant, which illustrates that inflation is no recession indicator. Possible explanations could be that inflation can increase through high demand (positive for growth) and shocks in supply (negative for growth).

These results confirm that an inverted yield spread is a significant predictor for recessions. With that, we statistically validated the first hypothesis – the spread can now be interpreted as indicator for recessions.

The next hypothesis examines whether the predictive power of the yield curve was influenced by the ECB's monetary policy measures after the 2008 financial crisis. The ECB introduced unconventional monetary policy measures, like zero or negative interest rates, QE or LTRO programs for banks. If these measures have influenced the relationship between spread and recession, we expect a weakened forecasting power after the financial crisis.

To test this, we defined a variable for the post-2008 period and let it interact it with the spread. Therefore, the new "Spread Interaction" variable represents the product between the time period post-2008 and the spread and was introduced in equation (2).

Probit Regression Post-2008 Result

	Dependent variable:
	Recession
Spread_10Y_3M	-0.223
	(0.237)
Spread_Interaction	0.417*
	(0.224)
GDP_Growth	-0.111***
	(0.036)
HICP	0.038
	(0.046)
Intercept	-0.678***
	(0.170)
Observations	244
Log Likelihood	-135.345
Akaike Inf. Crit.	280.691
Note:	*p**p***p<0.01

Table 4: Probit Regression Post-2008 Result

In these results, represented in table 4, the interaction variable is positive and a weak level of significance, implying that the predictive power of the spread became weaker after 2008. This means that after the financial crisis, the spread has become less important as an indicator of recessions, still the level of significance shows that it had somewhat predictive power after the financial crisis. ECB's measures may have distorted the link between the interest rate structure and the recession, but not completely. Before 2008, the yield curve was possibly driven by market forces and after 2008, ECB monetary policy dominated, possibly the unconventional measures. This weakening of the predictive power partially validates our second hypothesis, as the significance level indicated that there still is prediction power after 2008.

The hypothesis whether macroeconomic control variables influence the predictive power of the yield spread has the intention to examine if macroeconomic variables (GDP growth and inflation) overshadow or influence the predictive power of the spread. If these factors weaken the link between the spread and recession, this could mean that the yield curve is no longer an independent indicator but is influenced by macroeconomic conditions.

To do so, we will compare models with and without macroeconomic variables. There will be two probit models in addition to our first regression (1): First, a baseline model, equation (3), where the spread is the only independent variable – The purpose of this model is to analyse if the spread alone can predict recession. Then we will reconsider (1) (results in table 3), with the macroeconomic variables included. Table 6 shows an interaction model (4) between spread and GDP growth/HICP respectively. It will test if the influence changes in respect to the macroeconomic variable. If the spread is significant in the baseline model but no longer significant after adding the macroeconomic variables, this would mean that macroeconomic variables are superimposed on the effect – which we can already neglect by the results from table 3. But if the interaction effect is significant, this shows that the predictive power of the spread varies depending on the economic situation. If the spread remains significant in all models, this means that the interest rate structure remains a strong indicator regardless of the economic environment.

Probit Regression Baseline Result

	Dependent variable:
	Recession
Spread_10Y_3M	-0.228***
	(0.083)
Intercept	-0.818***
	(0.131)
Observations	244
Log Likelihood	-143.356
Akaike Inf. Crit.	290.711
Note:	*p**p***p<0.01

Table 5: Probit Regression Baseline Result

The results in table 5 confirm the significance of the spread coefficient – a lower spread increases the recession probability, as seen before in this analysis. But the spread could be a proxy for economic data, therefore it is important to reconsider our first regression and the further regression results.

As described, table 3 already gives us the results for a model with added macroeconomic variables – therefore, we are going to put them directly into perspective for this context. As the spread coefficient remains negatively significant, it can therefore be treated as a self-contained indicator for recessions based on the results. The results for the last model for this analysis (table 6), examines whether the predictive power of the spread is influenced by macroeconomic indicators by taking interaction effects into account.

Probit Regression Interaction Result

	Dependent variable:
	Recession
Spread_10Y_3M	-0.411**
	(0.187)
GDP_Growth	-0.030
	(0.049)
HICP	-0.257**
	(0.109)
Spread_GDP_Interaction	-0.121***
	(0.042)
Spread_HICP_Interaction	0.298***
	(0.089)
Intercept	-0.080
	(0.249)
Observations	244
Log Likelihood	-129.536
Akaike Inf. Crit.	271.072
Note:	*p**p***p<0.01

Table 6: Probit Regression Interaction Result

The significantly negative value for the interaction variable between GDP growth and the spread implies that if the GDP is high, the influence of the spread on the recession probability is weaker and vice versa. This implies that in phases of strong economic expansion, the yield curve becomes less meaningful, as the overall probability of recession is low. The value for the interaction variable between the HICP and the spread is significantly positive. Implying that when inflation is higher, the effect of the spread on recessions increases. High inflation often leads to restrictive monetary policy (e.g. interest rate increases by the ECB), which influences the interest rate structure and thus increases the probability of recession.

As the spread coefficient stayed significant in all models, the macroeconomic variables do not overshadow the prediction power the yield has. But nevertheless, the interaction effect is significant, which shows that the predictive power does indeed depend on the macroeconomic indicators, even if the spread is significant for itself and therefore a strong indicator. The spread is therefore not a static indicator but has different effects depending on the macroeconomic situation. For this model this means that if economic growth is strong, the yield becomes less relevant for recessions. And if inflation is high, the spread becomes more important as an indicator of economic downturns. This validates the third hypothesis.

4.3. Robustness

Robustness checks are crucial for testing the stability and reliability of the empirical results. For this purpose, an alternative model approach is tested (logit), lags of the explanatory variables are taken into account (t - 3, t - 6) and the performance of the model is evaluated with two methods.

For the first robustness test, we will estimate a logit model as described in chapter 3.3, equation (5). Probit and logit models are very similar, but logit has a different distribution assumption (logistic distribution instead of normal distribution) (Wooldridge, 2019). Therefore, it makes sense to test a logit regression as an alternative because if the logit model delivers similar results, this shows that the results are robust to the choice of model.

The results in table 8 (see Appendix) show that the spread coefficient remains significantly negative. Therefore, we can conclude that the spread remains robust against the choice of model. The level of significance and general impression of the result is the same, therefore the

interpretation remains sound for both models. As the interaction effects remain significant, we can see that GDP growth and HICP still influence the prediction power of the spread.

As macroeconomic events, such as recession, often have a lagged effect on the economy, lagged variables (t – 3 and t - 6) are included in the model, represented in (6) and (7) respectively. If the spread coefficient remains significant with the lags, it will prove that the yield spread works as an early indicator in the mid- and long-run. The test results in table 9 (Appendix) show that neither of the lags is significant, while GDP growth remains significantly negative. In contrast, HICP remains insignificant and has therefore no influence. The spread is therefore a short-term indicator, but not necessarily a leading indicator for 3 or 6 months. Hypothetically, this could indicate that the ECB's monetary policy after 2008 has led to more short-term reactions to the yield curve. Alternatively, it could also mean that other macroeconomic factors have a stronger short-term impact than the spread.

For the last robustness test, we will examine the performance of the model with two approaches: The AUC score under the ROC curve and McFaddens R^2 both for equation (4). The goal is to evaluate how well the model distinguishes between recession and non-recession. While the the AUC score (8) shows how well the model can distinguish, McFaddens R^2 (9) measures the explanatory power of the model. Figure 2 shows the visualization of the ROC curve for our probit model.

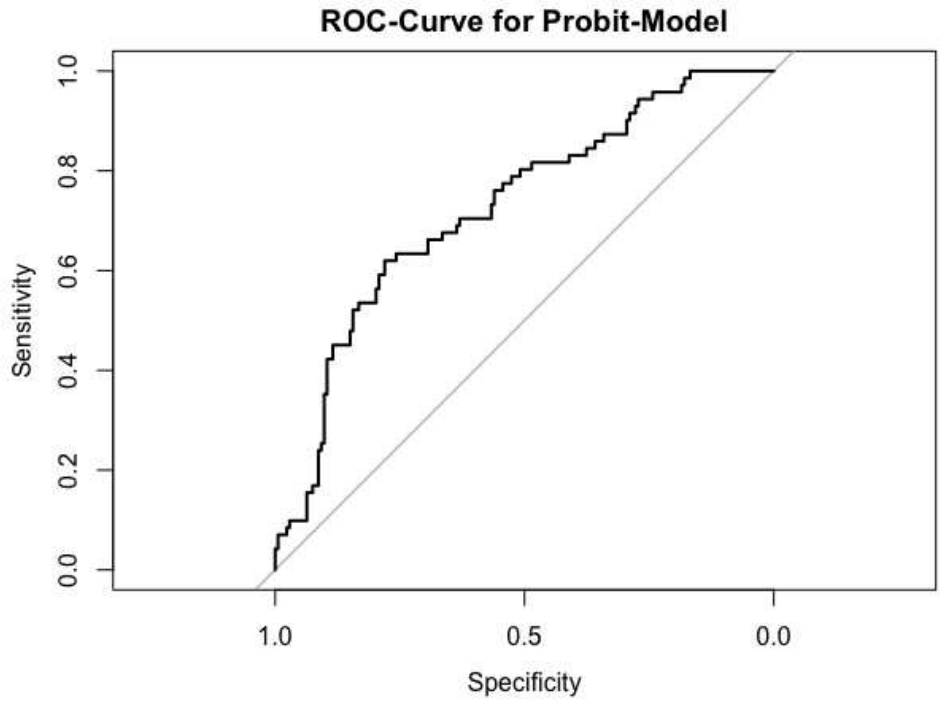

Figure 2: ROC Curve for Probit Model

The AUC score, the area under the ROC curve, is 0.7257, which means that the model has a moderate prediction power. The threshold for random prediction is 0.5, therefore the model has a certain prediction power – even if not a very precise one, which indicates that further factors could play a role. The McFadden R^2 value, obtained in table 10, is 0.1196, which is a weak result. It implies that this model has somewhat of explanatory power but is not classified as a good explanatory model. The model can predict recessions better as a coincidence, but not with high precision. Other macroeconomic variables could improve the prediction power.

Summarizing, the tests show that the probit model choice was sound, showing robustness in the alternative model. The spread however shows predictive power rather in the short term, but not in the mid- or long-term (as t-3 and t-6 are not significant) and the performance of the model could be improved by further macroeconomic variables and factors included.

5. Discussion

5.1. Interpretation of results

The empirical results of this dissertation confirm that the spread between the 10-year and 3-month government bond yields in the Eurozone has certain predictive power for recessions. The probit regressions show that a negative or sharply declining yield curve correlates with an increased probability of recessions. This is consistent with earlier empirical studies from the US (Estrella & Mishkin, 1998) and with studies on the Eurozone (Chinn & Kucko, 2015). The results suggest that the yield spread remains a useful, but still imperfect, indicator of economic downturns.

The estimation of the probit model showed that the spread coefficient is negative and significant ($p < 0.05$), indicating that an inverted yield curve increases the probability of a recession in the Eurozone. This validates the first hypothesis that the 10Y-3M spread continues to be a leading indicator for recessions. However, the robustness test with time lags (t - 3, t – 6 months) shows that the spread loses its significance over longer periods, which indicates that its predictive power is more short-term.

The second hypothesis, that the predictive power of the yield curve changed after the 2008 financial crisis due to the ECB's expansionary monetary policy, was partially confirmed. The interaction variable between the spread and the post-2008 period showed that the spread has a weaker but still significant predictive power after 2008. This is partially consistent with the hypothesis that unconventional monetary policy measures by the ECB, such as QE and negative interest rates, have caused structural distortions in the yield curve (Altavilla et al., 2018).

The third hypothesis which indicates that other macroeconomic factors overshadow or influence the predictive power of the spread, was investigated by analyzing the interaction between the spread, economic growth (GDP growth) and inflation (HICP). The results show that strong economic growth weakens the predictive effect of the spread, while high inflation strengthens the predictive power of the spread. This indicates that the yield curve should not be viewed in isolation but must be interpreted in conjunction with macroeconomic indicators (Bernanke, 2018). The yield curve is not overshadowed by them, but still significantly influenced.

The results of this study are consistent with earlier research on the predictive power of the yield curve. Estrella & Mishkin (1998) already showed for the US that an inverted yield curve in

almost all cases heralds a recession within 12 to 18 months. Chinn & Kucko (2015) and Duarte et al. (2005) come to similar conclusions for the Eurozone. However, there are two significant differences to the existing literature:

- Earlier studies have not sufficiently considered the role of unconventional monetary policy and its distortions. Since the 2008 financial crisis, QE programs and negative interest rates have changed market dynamics, which has led to a partial weakening of the predictive power of the yield curve (Svensson, 2019).
- Also, the interaction effects with macroeconomic factors are an important difference. While earlier work has mostly considered the spread in isolation, this study shows that inflation and economic growth can modulate the predictive power of the spread. This is in line with more recent work that argues that inflation- and growth-related changes in the term structure of interest rates have a decisive influence on recession forecasts (Ng & Wright, 2013).

The empirical analysis answers the central question of this dissertation by showing that the spread has a certain predictive power, but with limitations. The three main findings in this dissertation include that the yield spread is significant for short-term predictions but loses power for longer periods (e.g. t - 3, t – 6 not significant). Also, the prediction power decreased after the financial crisis 2008 – probably because of the ECB interventions. The last main finding is that macroeconomic indicators influence the prediction power of the yield, especially inflation increases the effect of the spread while GDP growth decreases the effect – therefore the yield spread should not be examined isolated but in a context of macroeconomic development.

The results underline that the spread continues to serve as a useful, but imperfect, leading indicator for recessions in the Eurozone. Future studies should incorporate other macroeconomic factors to increase predictive power.

5.2. Limitations

While the empirical analysis of this dissertation provides important insights into the predictive power of the yield curve in the Eurozone, there are several limitations that must be taken into account when interpreting the results. These limitations relate in particular to the availability of data, the choice of model, the robustness of the results and possible alternative influencing factors.

A central methodological problem lies in the limited availability of historical data. The analysis covers the period from 2004 to 2024, which covers a significant economic period with several crises (2008 financial crisis, Euro crisis and COVID-19), but is not sufficient to carry out a comprehensive long-term analysis. Earlier studies, particularly for the US (Estrella & Mishkin, 1998), were able to draw on significantly longer data series, which led to more robust conclusions. The yield curve data for government bonds was only publicly available for triple A-rated bonds from the 6th of September 2004 onwards on the ECB data portal. Furthermore, recession indicators for the Eurozone are only available to a limited extent – The recession indicator was only available until the 31st of August 2022. With the forward fill technique, I then assumed that there is no recession after that date as the previous data indicated. Therefore, even if the yield curve was heavily inverted from January 2023 until recently, I couldn't possibly consider any period after mid 2022 as a recession in order to stay sound with the data. Also, OECD recession indicator-based quantified data was used, which is based on certain economic characteristics but does not always have to agree with other economic institutions. The definition and data basis of the recession indicator may therefore have influenced the result.

The choice of the probit model to estimate the probability of recessions is based on extensive economic literature (Bauer & Mertens, 2018a; Greene, 2012; Wooldridge, 2019). However, a potential drawback of this approach is that it may not fully capture non-linear relationships and structural breaks. Alternatively, machine learning methods or non-parametric models could have been used to enable more flexible modeling (Ng & Wright, 2013).

In addition, the model was estimated with a binary indicator for recessions. This could be problematic as economic downturns are often a continuous phenomenon that is not always accurately captured by a 0-1 classification. An alternative modeling with recession probabilities or macroeconomic downturn indicators could provide more precise insights (Bauer & Mertens, 2018a).

The robustness tests carried out, show that the predictive power of the spread is limited. It is particularly problematic that the spread does not remain significant with longer time lags (t - 3, t – 6). This is in contrast to results from the US, where the yield curve can usually forecast recessions with a lead time of 12 to 18 months (Chinn & Kucko, 2015).

Another weak point is the low model performance, measured by McFadden R^2 (0.1196). A McFadden R^2 below 0.2 indicates that the model explains only a relatively small part of the

variability of recessions. This suggests that further macroeconomic variables would be required to improve the model quality (Ng & Wright, 2013).

A major problem in interpreting the results is the role of the ECB's monetary policy. After the 2008 financial crisis, unconventional measures such as negative interest rates and QE meant that the yield curve was no longer fully determined by market expectations but was partially distorted by direct interventions of the ECB (Altavilla et al., 2018). This could have weakened or changed the typical inverse relationship between the yield curve and the economy. Especially it is difficult to obtain sound results on what measure influenced the yield curve prediction power in what way.

In addition, only a limited number of macroeconomic control variables were considered in this study. While GDP growth, which has a weak negative correlation with recession, and inflation were included, other factors such as the unemployment rate, credit growth, consumer climate indicators could offer additional explanatory power (Bernanke, 2018). Also, examining corporate bond spreads could be a good addition. Future studies should therefore use advanced macroeconomic models to examine whether other indicators should be included in a model as well.

Concluding, although the obtained results confirm the existing literature, there were factors that have limited this model and could be considered in future studies.

5.3. Implications

As the empirical results of this dissertation have shown that the yield curve in the Eurozone continues to have a certain predictive power for recessions, it still is influenced by the ECB's monetary policy measures and macroeconomic factors. This has far-reaching implications for the ECB's monetary policy and for agents on the financial markets.

Since 2008, the ECB has introduced several unconventional monetary policy measures, including negative interest rates, QE, LTRO as well as long-term guidance of the interest rate expectations. As a result of these measures, the classic market mechanics behind the yield curve are no longer fully determined by supply and demand, but by direct intervention by the ECB. This could explain why the predictive power of the spread declined after the financial crisis (Svensson, 2019). As the yield curve is influenced by monetary policy measures, the question

arises as to whether the ECB can continue to use it as a leading indicator for economic downturns. The results of this study suggest that the 10Y-3M spread lost somewhat predictive power after 2008, indicating that the ECB should not rely solely on this indicator. Alternative indicators for the ECB could be the employment rate and wage growth as early indicators for a diminishing labor market. Credit and corporate bond spreads could also be a signal for financing conditions in the real economy (Bernanke, 2018). Additionally, the expectations on inflation and the consumer climate index could give direct hints on future consumer demand.

But the results of this dissertation also have consequences for financial market agents, especially investors and banks, who use the yield curve as a signal for future economic changes. Historically, an inverted yield curve has been a strong warning signal of coming recessions. In the US, investors have traditionally relied on this indicator to make strategic portfolio adjustments (Chinn & Kucko, 2015). However, the analysis for the Eurozone shows that the predictive power of the spread is distorted by ECB interventions which means that investors should not rely exclusively on this indicator but must combine it with other macroeconomic factors. Strategic adjustments for investors could include the consideration of factors such as lending and corporate bond spreads which should be increasingly included in recession forecasts. Still, for the diversification of portfolios, in times of inverted yield curves, a greater focus should be placed on low-risk investments (e.g. gold). The ECB politics should also be considered more: The effect of monetary policy on the interest rate structure should be systematically incorporated into risk models.

Market reactions to inverted yield curves could continue to change in the future, considering the results of this dissertation. Reactions like less severe capital market corrections, with markets reacting less to inversions than in the past or increasing uncertainty in interest rates with investors placing more emphasis on macroeconomic data instead of relying solely on the yield curve, could occur. Probably the demand for alternative early indicators such as credit risk premiums and market volatility could also rise.

In summary, the results of the dissertation show that an extended analysis of macroeconomic indicators for financial markets and monetary policy is required.

6. Conclusion

This dissertation investigated whether the yield curve for triple-A rated government bonds (10Y-3M spread) continues to be a reliable leading indicator for recessions in the Eurozone. An empirical analysis using probit models was used to examine the extent to which the spread was able to predict recessions in the years 2004 to 2024 and how macroeconomic factors and monetary policy interventions influenced this relationship. The results provide valuable insights for academic research as well as for financial market agents and central banks.

The empirical results show that the yield curve in the Eurozone has a certain predictive power for recessions, but that this has been modified by the ECB's monetary policy measures and macroeconomic factors. The three central findings include that the 10Y-3M spread remains a relevant leading indicator for short-termed forecasts, losing power for longer periods, but also that its predictive power has been weakened by monetary policy since 2008. Additionally notable is that macroeconomic factors such as inflation and economic growth influence the predictive power - in particular, strong economic growth weakens the predictive effect of the spread.

Overall, it is implied that the yield curve can still be regarded as a strong predictor for recessions in the Eurozone, but no longer with the same reliability as in previous decades.

The dissertation contributes to economic research on this topic and confirms earlier findings (Estrella & Mishkin, 1998; Chinn & Kucko, 2015). Future studies should examine alternative leading indicators, especially those that are not directly influenced by central bank measures, such as credit spreads or labor market indicators (Bernanke, 2018). The results have also far-reaching consequences for the ECB - The fact that the predictive power of the yield curve has decreased since the financial crisis could lead to the conclusion that the ECB needs to rethink its monetary policy strategy, also here the consequence could be to consider alternative early indicators which are not distorted by monetary policy. For financial market agents, this means that although the yield curve is still a relevant indicator, it should no longer be viewed in isolation. Instead, it should be analyzed in combination with other macroeconomic indicators such as inflation and economic growth, but also further indicators.

Despite the insights gained, there are some limitations of this dissertation that future research should take into account. This analysis is based on a period from 2004 to 2024, whereas previous studies for the US were able to draw on data series spanning more than 50 years. A

longer time series could provide more robust results. Also, the probit model used is a classical approach for modeling binary events, but future research could use machine learning techniques or non-parametric methods to capture more complex non-linear relationships (Ng & Wright, 2013). It is also worth mentioning that even if this analysis focused on the 10Y-3M spread, other financial indicators, such as credit spreads or corporate bond spreads, could also serve as leading indicators of recessions (Bauer & Mertens, 2018a). It would also be of interest to test further macroeconomic factors in a model and their influence on either the yield curve or other indicators of recession. Comparing green bonds to government or corporate bonds in their prediction power, could also be an addition to this dissertation.

Particularly, in complex geo-political and economic situations, which we faced in the past and keep facing, including the current war in the Ukraine, an early indicator of recessions is valuable for all stakeholders in politics, regulatory and financial markets. The central question of this dissertation was therefore whether the yield curve is still a reliable leading indicator for recessions in the Eurozone or whether it got distorted. The empirical results prove its ability to be a leading predictor, but also show that the yield curve is no longer indisputable. The ECB's monetary policy has changed its predictive power since the financial crisis, meaning that investors, central banks and researchers should no longer rely exclusively on this indicator. Still, these results can serve as a basis for further economic and financial market research.

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Appendix

Table 7: Marginal Effects Probit Regression

factor	AME	SE	z	p	lower	upper
GDP_Growth	-0.0370	0.0106	-3.4952	0.0005	-0.0577	-0.0163
HICP	0.0115	0.0147	0.7808	0.4349	-0.0173	0.0403
Spread_Corrected	-0.0604	0.0258	-2.3384	0.0194	-0.1109	-0.0098

Table 8: Logit Regression Interaction Result

Logit Regression Interaction Result

	Dependent variable:
	Recession
Spread_10Y_3M	-0.706**
	(0.324)
GDP_Growth	-0.042
	(0.083)
HICP	-0.451**
	(0.196)
Spread_GDP_Interaction	-0.202***
	(0.073)
Spread_HICP_Interaction	0.513***
	(0.158)
Intercept	-0.090
	(0.426)
Observations	244
Log Likelihood	-129.843
Akaike Inf. Crit.	271.687
Note:	*p**p***p<0.01

Table 9: Probit Lag Model Result

Probit Lag Model Result

	Dependent variable:
	Recession
Spread_Lag3	0.296
	(0.229)
Spread_Lag6	-0.140
	(0.233)
GDP_Growth	-0.114***
	(0.036)
HICP	0.030
	(0.046)
Intercept	-0.658***
	(0.169)
Observations	238
Log Likelihood	-135.782
Akaike Inf. Crit.	281.563
Note:	*p**p***p<0.01

Table 10: McFadden R^2 Result

```
llh      llhNull           G2     McFadden          r2ML          r2CU
-129.5357910 -147.1393299   35.2070778    0.1196386    0.1343645
0.1917778
```