The Term Structure as a Predictor of Real Economic Activity

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Abstract

The inversion of the yield curve is interpreted by financial markets as the prelude to a forthcoming economic recession. The predictive ability of this economic instrument to predict future growth rates of real economic activity, as well as economic recessions is examined. In addition, a selection of three countries belonging to the European Union, namely Germany, France and Spain, where we use a linear regression model and a probit model to test the predictive ability of this possible leading economic indicator is studied.

Specific results for each country are obtained, concluding favourably in the analysis of Germany, and with less relevant results for France and Spain. However, given the simple application and interpretation of this tool, we consider it a relevant instrument to predict the economic future.

Keywords: yield curve, real GDP growth, recessions, probit

JEL classification: E37, E43

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INTRODUCTION

Economic recessions are periods of economic decline, specifically when the rate of change of GDP is negative for two consecutive quarters. These periods of economic slowdown have a direct impact on economic agents, governments, businesses and families. They actively participate in economic activity through their production, consumption, savings and investment decisions. Therefore, in the event of an economic crisis, their economic and social situation could be significantly affected. The consequences of an economic slowdown or contraction can reach significant levels, in which long periods of time may be needed to recover previous economic levels or significant growth rates.

Because of this economic phenomenon, it is logical to understand that economic agents need to reduce or eliminate as far as possible the uncertainty that may occur in the future economic environment, that is, to try to predict changes in the economic cycle in order to anticipate them. If economic agents succeed in this difficult and complex task, they will have the ability to correct and adjust their economic strategies to their new expectations. Understanding and comprehending the economic environment in which we live will help us to make better decisions, and consequently, to face the economic future with better guarantees.

At this point, governments, companies and families need to know the economic instruments, forecasting techniques or econometric models offered by economic science in order to deal with the problem of economic uncertainty and to be able to anticipate economic cycles. Therefore, having the ability to predict the arrival of an economic recession will allow us to better face these times of economic turmoil. Knowing what tools economic science offers us, which one is the most appropriate for each situation, and how to apply and interpret them, will provide us some advantages in our decision-making.

What is the yield curve?

In this research, we are going to focus our study on the analysis of a macroeconomic technique tool, commonly used by economists and experts from the financial world to predict changes in the business cycle and anticipate economic downturn. We are referring to the yield curve. The yield curve or interest rate term structure, is an economic technique instrument that graphically represents the relationship between payment times and interest paid on bonds issued by the same government or public entity. This is an economic forecasting tool, which has historically enjoyed a reputed scientific recognition when it comes to predicting the future direction of the economy.

At this point, several questions arise: why is so much attention paid to the yield curve? What value does economic science place on this instrument? Is this predictive instrument so effective? In this study, we will try to analyse in detail a series of econometric models that allow us to answer all these questions.

What does an inverted yield curve mean?

Our research focuses on analysing the inversion of the yield curve. This inversion of the slope has been interpreted by many economists as the prelude to economic recessions. Therefore, we are going to study the relationship between this fact and real economic activity, and whether the inversion of the curve indicates the arrival of an economic recession. Knowing how to interpret the causes and consequences of the reversal of the slope can be of great help in predicting changes in the economic cycle.

Theoretically, the inversion of the slope of the yield curve indicates that the public debt of a certain government or public entity is more profitable in a short term than in a long term. That is, a government offers a higher return for lending money in the short term than in the long term. In the following sections, we are going to explain in detail why this economic fact occurs. However, we can anticipate that the reasons that can explain the inversion of the yield curve would not be hopeful for the future of the economy.

Is the yield curve a good predictive tool?

There is scientific evidence that indicates the connection between the yield curve and real economic activity. Several investigations provide us empirical evidence on the good predictive performance of the yield curve. However, we also find some contradictions in the application and interpretation of this macroeconomic technique and the results it provides us.

Our purpose will be to test the application and interpretation of this economic indicator, and to know if it can provide us meaningful information regarding future changes in the economic cycle. We are going to study the behavior of this tool for the case of Germany, France and Spain. To carry this out, we are going to rely on the economic methodology used by Estrella and Hardouvelis (1991) in their research of the economy of the United States.

At this point, we can define and specify the object of our study. This will answer the following question: Is the yield curve a good predictive instrument for changes in the business cycle? To answer it, we are going to carry out an exhaustive research structured as follows:

- *Bibliography Review*: we are going to proceed to an exhaustive review of the scientific literature regarding our object of study. This review will make it easier for us to access and learn about the methodological approaches, questions and results reached by the different researchers who have addressed this issue. Furthermore, the knowledge that this review will provide us with will help us to specify and define our line of research, in order to be able to make a new contribution to the literature.
- *Empirical Methodology*: we are going to detail the theoretical bases that economic science provides us with reference to the yield curve. We are going to continue explaining the search and selection of data and variables, and we will end with the incorporation of econometric models.
- *Analysis of results*: we are going to analyse the results obtained in the econometric models applied in this study, and we are going to rely on tables and graphs to compare the results.
- *Conclusions*: finally, we are going to assess and respond to the object of study, that is, to answer whether the yield curve is a good predictor of real economic activity and changes in the business cycle. In short, we are going to try to verify if the conclusions to which our research leads us are supported by economic science and previous research.
- *References:* we are going to incorporate all the sources consulted in the preparation of this research.

REVIEW OF THE LITERATURE

A detailed study of the literature review will allow us to learn about the contributions previously made by experts in the field. This section is particularly important, due to the fact that a proper literature review and a complete analysis of it will allow us to specify our lines of research. We have found numerous scientific papers that attempt to explain the predictive capacity of the yield curve. This extensive literature denotes the great attention that has historically been paid to this economic indicator, so we will try to check whether we obtain the same conclusions as those reached previously. Specifically, we will focus our study on explaining the yield curve as a predictive instrument of real economic activity for Germany, France and Spain.

For the elaboration of our research, we will follow the methodology applied by Estrella and Hardouvelis (1991). They carry out an exhaustive analysis of the yield curve as a predictor of real economic activity in the United States.

Estrella and Hardouvelis (1991) noted that the slope of the yield curve had been used in previous research to predict future spot interest rates, and the results provided by the application of this economic indicator must be positive. Given these observations, these authors set out to investigate whether the yield curve would be able to explain the growth of real economic activity. These authors believe that given the quasi-random behaviour of the real GNP, the conclusion that the yield curve could predict changes in real economic activity gains significance.

These authors carried out a detailed analysis of the predictive capacity of this economic instrument for the case of the United States. In their study, they delimit a sample of data for a time period starting in 1955:Q1 and going up to 1989:Q4 (working with quarterly data). In order to analyse the behaviour of the yield curve in relation to real economic activity and future economic recessions, they study a linear regression model and a probit model.

This research by Estrella and Hardouvelis (1991), which we use as a model for our research, has been referenced by other researchers who have tried to analyse the same issue. Among others, we can highlight the research carried out by Dotsey (1998), which confirms the conclusions of these authors in relation to the predictive power provided by the yield curve. In this respect, we would also like to highlight the research by Henry and Phillips (2020), Adbymomunov (2013), Wright (2006) and Atta-Mensah and Tkacz (1998).

On the other hand, we note that a large number of these studies focus on the case of the United States. For example Estrella and Mishkin (1996), Estrella and Mishkin (1998), Dotsey (1998), Zaloom (2009), Abdymomunov (2011), etc. We consider that this fact could come from the important economic, political and social size of the North American country, which is the first economic power in the world. However, not all research has to deal with the US economy, as we find other works that analyse the predictive capacity of the yield curve for other economies. Among others, we can cite the study by Atta-Mensah, J., & Tkacz, G. (1998) who analysed the case of Canada, we can also highlight the research by Estrella, Rodrigues and Schich (2003) who carry out a comparison between Germany and the United States, and finally we can highlight the work by Henry and Phillips (2020), who carry out a comparative study for New Zealand, Australia and the United States.

With reference to economic theory, all the scientific articles consulted provide valuable information on the relationship between the yield curve and real economic activity. Moreover, this instrument of economic technique could also be a good indicator for other variables, such as future spot interest rates, inflation or stock prices, as Estrella y Mishkin (1998) indicate in their work, where they investigate these economic relationships. Other authors such as Mankiw and Miron (1986) provide interesting information on this economic relationship, where they focus their study on the importance of the theory of expectations.

One example we would like to cite is the research of Dotsey (1998), who argues in his research that the prices of different securities incorporate expectations of future economic activity. This author considers that the use of financial variables could help in economic projections, within the financial variables he focuses on the study of the yield curve, i.e. the spread between long-term and short-term bond interest rates. In his article, he concludes that the spread is generally a useful variable for predicting future real GDP growth, but he does note that this indicator has lost predictive power in recent years.

On the other hand, with reference to the econometric models used to study this economic relationship, we find similarities in the research cited, as many authors rely on the same econometric models to answer this question. For example, Wright (2006) compares different probit models to test the relationship of the yield curve as a predictor of economic downturns, noting that the shape of the yield curve provides more information about the likelihood of economic downturns than the term spread alone. The probit model, which uses the term spread alone, predicts high probabilities of a crisis in the next four quarters, while the other probit models estimates, which control for the level of

fund interest rates, do not perform as well. On the other hand, Atta-Mensah and Tkacz (1998) conduct a study using a number of financial variables to predict economic recessions in Canada. They rely on the econometric methodology employed by Estrella and Mishkin (1998) using a probit model to predict the arrival of future recessions eight quarters ahead. Their main conclusion is that the spread of long-term versus three-month interest rates is a suitable tool for predicting Canadian recessions. This is consistent with the results of Estrella and Mishkin (1998).

Finally, we would like to highlight a paper that we consider relevant to analyse, namely the one carried out by Estrella, Rodrigues and Schich (2003). These authors argue that the theoretical motivations that explain the relationship between the yield curve and real economic activity may not be stable over time. To test this fact, they apply different econometric techniques to find out whether these empirical relationships are indeed stable. They conclude that models predicting real economic activity are more stable than models predicting inflation. They also find that binary models are more stable than continuous models, and that these binary models behave well throughout the period analysed, both for Germany and the United States.

We consider that the latter research to which we refer will be useful in our research, since these authors, like us, analyse the application of the yield curve to the German economy, so we will compare their conclusions with ours.

After observing and analysing all the research we have just referred to, we can define our lines of research more precisely. We will study a linear regression model and a probit model, with the aim of finding out the predictive capacity of the yield curve for the selected countries, as well as analysing whether this economic technique has lost some of its predictive capacity in recent years, as certain articles indicate. Finally, this review of the literature will allow us to compare the conclusions reached with those obtained previously by different experts in the field, thus enabling us to carry out a critical and well-founded study.

EMPIRICAL METHODOLOGY

The study of the empirical methodology is a fundamental and concrete part of any scientific research work. This analysis is based on a theoretical study, supported by observation and analysis, which will allow us to determine the existing economic relationships between the variables under study. This approach will enable us to specify and define our economic model and, subsequently, the appropriate econometric techniques or models to evaluate the hypotheses and test the value of the economic theory.

In line with the approach above, we begin with an analysis of the research accomplished by Estrella and Hardouvelis (1991). They carried out a study of the yield curve and its power to predict real economic activity in the United States. Our objective in analysing this research will be to understand the methodology applied by these authors in order to subsequently reproduce their results. This procedure will allow us to be sure that we have understood the methodology and the analysis applied. Thus, we can later apply this same analysis to our own research, where we will study how this instrument behaves in the two main European economies, Germany and France, and we will also analyse the case of Spain.

While analysing the work of Estrella and Hardouvelis (1991), we will examine the yield curve and its relationship with real economic activity from an economic theory perspective. This will enable us to gain an in-depth understanding of the value of this tool and its theoretical ability to predict future changes in the business cycle.

The next step is to search for, select and analyse the economic data. At this point, we will define the structure and characteristics of the data and variables that we will later estimate in the econometric models.

Finally, once the economic model and the data structure have been defined, we will go on to explain the theoretical bases of econometric models, as well as the problems we detect in the process of applying and estimating these models. As we know, econometrics is a discipline that has become a very important science in the development of data and statistical information. It is of great relevance in the process of estimating and evaluating economic relationships, economic theories, public policies and business strategies.

In conclusion, following this approach we will be able to carry out a structured study that will allow us to verify the value of this tool in terms of its ability to predict changes in the economic cycle for Germany, France and Spain.

Estrella y Hardouvelis (1991)

As we have just explained, the elaboration of our work begins by observing and analysing previous research. For our study, we will apply the methodology carried out by Estrella and Hardouvelis (1991) in their analysis of the yield curve as a predictive tool for real economic activity in the United States.

According to this approach, our first objective will be to understand the methodology applied by these authors, in order to subsequently be able to reproduce their results in the United States. In this way, we will know for sure that we understand the application and interpretation of the econometric models used. Subsequently, we will be able to apply the same analysis to our research, where we will study how this economic instrument behaves in Germany, France and Spain. Our aim will be to carry out a comparative study between the results obtained in each country and compare our conclusions with those obtained by Estrella and Hardouvelis (1991).

The first step before reproducing the econometric models is to carry out a search and selection of data, where we will have to try to reproduce the same database with which these authors work in their research.

First, we are going to proceed to analyse the linear regression model, which tries to explain the relationship between the yield curve and the growth of real economic activity. This econometric model is defined as follows:

Equation 1.

$$Y_{t,t+k} = \alpha_0 + \alpha_1 SPREAD_t$$

where, $SPREAD_t$ is defined as the spread between long-term versus short-term US bond yields, specifically the spread between ten-year versus three-month yields.

With reference to data selection, at the FRBNY[1] web address, we find the database of the US bond yield spread, i.e., here we can find the $SPREAD_t$ data. However, the database mentioned shows the monthly $SPREAD_t$, so we will have to make a quarterly average to be able to estimate the model correctly. We also note that we will only have

[1] FRBNY: Federal Reserve Bank of New York's.

data from 1960:Q1 onwards, so we will not be able to study exactly the same period, as the original research covers a period from 1955:Q1 to 1989:Q4. However, we consider that these five years of difference will not be relevant so as to know if we have carried out a correct application and interpretation of this model, as the results must be very similar. On the other hand, we need the real GNP data, which can be found on the FRED[2] website address, these data are defined as, billions of chained 2012 dollars, seasonally adjusted annual rate.

Once the database has been developed, we proceed to estimate this model, from which we have obtained the following results:

Table 1.

Results of the linear regression model, for the United States (1960:Q1-1989Q4).

		Cumulative Change			
Forecasting Horizon; K Quarters Ahead	*Nobs.*	α0	α1	$\bar{R}^2$	SEE
1	119	2.07 *** (0.42)	1.40 *** (0.26)	0.19	3.54
2	118	2.19 *** (0.32)	1.31 *** (0.20)	0.27	2.67
3	117	2.26 *** (0.28)	1.25 *** (0.17)	0.31	2.31
4	116	2.35 *** (0.25)	1.17 *** (0.15)	0.33	2.07
5	115	2.49 *** (0.23)	1.06 *** (0.15)	0.31	1.95
6	114	2.62 *** (0.22)	0.95 *** (0.14)	0.28	1.84
7	113	2.77 *** (0.21)	0.82 *** (0.13)	0.24	1.76
8	112	2.90 *** (0.20)	0.69 *** (0.13)	0.20	1.68
12	108	3.21 *** (0.17)	0.37 *** (0.11)	0.09	1.43
16	104	3.40 *** (0.15)	0.17 * (0.10)	0.02	1.23
20	100	3.43 *** (0.13)	0.12 (0.09)	0.01	1.05

*Source: own elaboration, ***Significant at the 1% level, **significant at 5%, and *significant at 10%, in a two-tailed test.*

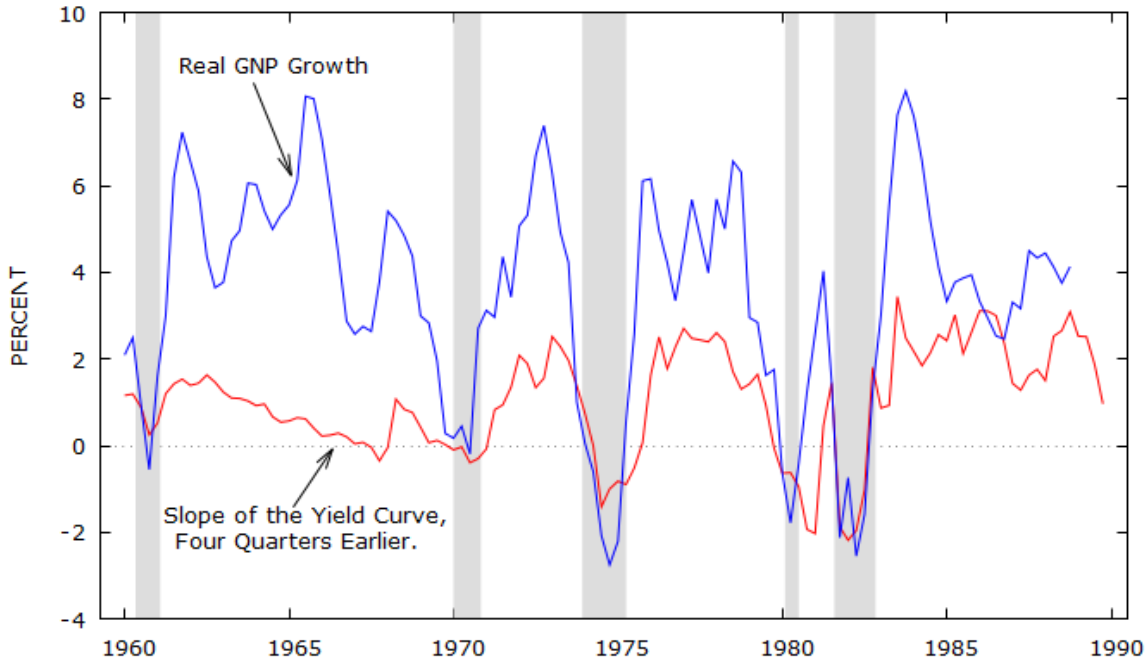
[2] FRED: Federal Reserve Economic Data

Comparing the results obtained to the results of the original research, we can observe remarkably similar results, and as we have explained previously, such small difference in the results is due to the fact that we do not have exactly the same sample of data. Taking into account this difference in the sample size, we can consider that we are obtaining correct results, since we have an $\bar{R}^2$ similar to the one obtained by the authors, and the model would be better explained in the same time horizons.

We now turn to a graphical representation of this relationship, where we can graphically corroborate the results obtained herein, where a four-quarter lagged yield curve would be a good indicator of the growth of real economic activity in the period analysed for the United States.

Figure 1.

The current growth in real GNP and the slope of the yield curve 4 quarters earlier for the United States (1960:Q1-1989:Q4).



Source: own elaboration. We use the econometric software Gretl

The second part of our research will try to reproduce and analyse the probit model. This analysis will allow us to find out what probability the four-quarter lagged yield curve predicts in reference to an upcoming economic recession. In the application of this econometric model, we have to take into account that the probit model uses a dichotomous dependent variable, i.e. a variable that has only two values, one and zero. The purpose of this model is to provide us with the probabilities of an economic recession happening or not.

This econometric model is defined as follows:

Equation 2.

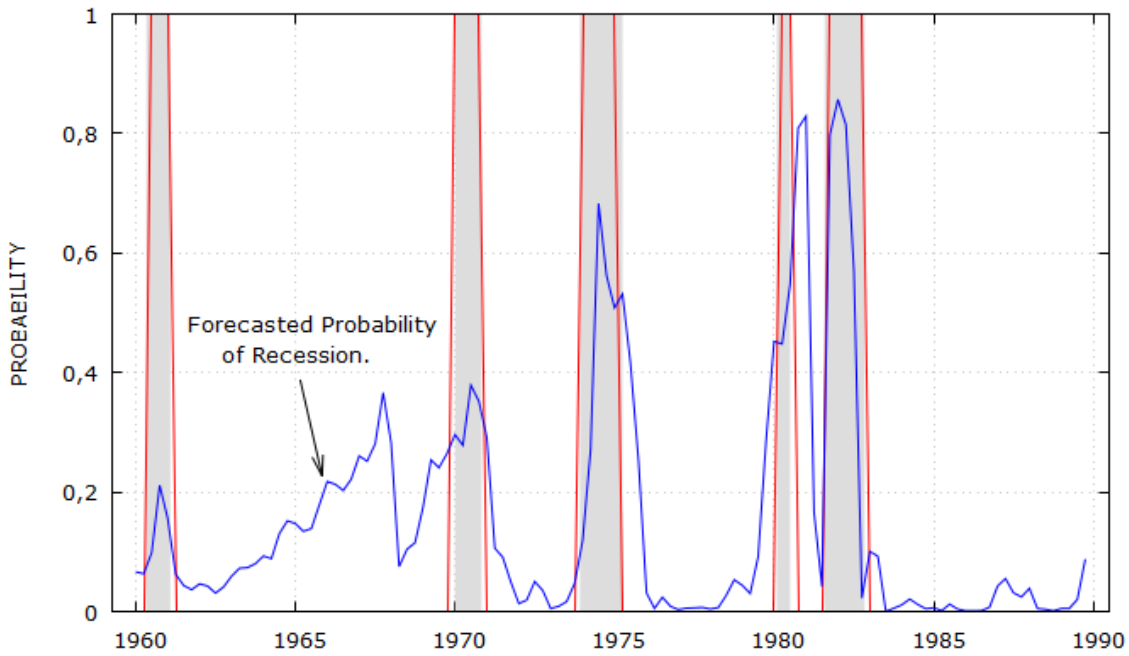
$$\Pr(\mathrm{X}=1|SPREAD_{t-k}) = \mathrm{F}(\beta_0 + \beta_1 SPREAD_{t-k})$$

where, $\Pr$ denotes probability, F is the cumulative normal distribution and X is equal to unity, during quarters considered as recessions.

In reference to the search for data, the data for the dependent variable (RECESSIONS) are found in the NBER[3] as indicated by the authors in their article. The periods considered as crisis by the NBER will adopt a value $(Y=1)$ and the periods of absence $(Y=0)$, operating with quarterly data. On the other hand, the explanatory variable will be the lagged in four quarters $(SPREAD_{t-4})$. Finally, we will rely on the econometric software Gretl to estimate the model. In the following graph we show the result obtained, and exactly the same results Estrella and Hardouvelis (1991) obtained can be observed. Consequently, we can be sure that we have understood the application and interpretation of the model.

Figure 2.

Forecasted probability of recession for current quarter based on the slope of the yield curve 4 quarters earlier for the United States (1960:Q1-1989:Q4).



Source: own elaboration, we use the econometric software Gretl.

[3] NBER: National Bureau of Economic Research.

The conclusions reached by Estrella and Hardouvelis (1991) in their research are very important, since according to them, the yield curve would be an instrument capable of predicting the future direction of real economic activity in the United States.

Our aim will be to follow this methodology and check whether the application of these econometric techniques could provide us with the same results and conclusions for Germany, France and Spain as those reached by these authors in their research.

However, we will have to take into account the time axis of the analysis, since this research we refer to is based on data from 1955:Q1 to 1989:Q4, while our research will focus its analysis on a current time frame. Moreover, we should also bear in mind that these countries that we are going to analyse share a common monetary policy and an interdependent economic structure as Member States of the European Union. Therefore, we consider that it is interesting to check whether this economic instrument would have the capacity to predict real economic activity in these countries, taking into account the current economic conditions and the political-economic structure of which they form part.

Economic Theory

We pay much attention to developing and studying the methodology applied by Estrella and Hardouvelis (1991). Nevertheless, we consider that it is necessary to carry out at the same time an in-depth analysis and a detailed explanation of the economic theory that explains the relationship between the yield curve and real economic activity. Economic science tries to understand and explain theoretically the facts and interactions that take place in the economic sphere from two different fields: macroeconomics and microeconomics.

As previously explained, the yield curve is a technical economic tool. It graphically represents the profitability of public debt at different maturities, i.e. it provides us relevant information on the differential of government bond yields at different periods, information which we consider important to understand and know how to interpret, as this indicator could be giving us information on the future direction of real economic activity.

The economic theory that explains the different forms that the yield curve can take, as well as the causes and consequences that would lead to each of these situations, will be analysed below. To analyse the different forms that the yield curve can take, we use the example of Germany in the context of the 2008 economic crisis.

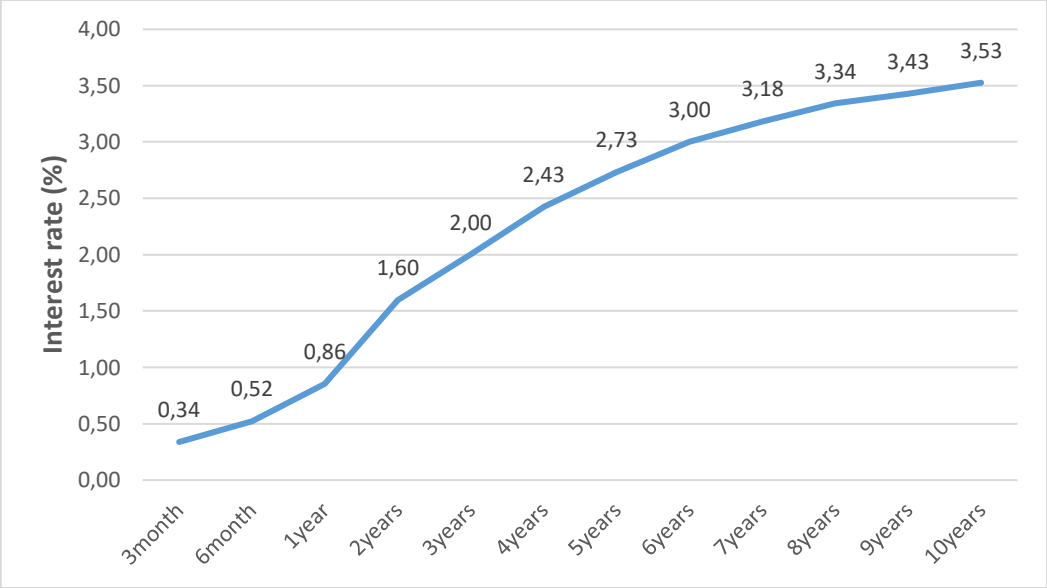
Normal shape of the yield curve

According to economic theory, the normal shape of the yield curve should have a positive slope, i.e. we understand that the return on debt should be higher as the maturity at which the money is lent increases.

In the chart below, we see the yields of German bonds at different maturities on the 7th of August 2009, where we can see the positive slope of the yield curve referred to above.

Figure 3.

German yield curve on 7 August 2009.



Source: own elaboration, investing.com data on 3-month to 10-year German bond yields for 7 August 2009.

As we can see, the 7th of August 2009, the yield curve was positively sloping, i.e. there was a higher yield on German government bonds as the maturity of the loan increased. For example, we observe that three-month German treasury bills yielded 0.34%, while ten-year bonds offered 3.53%.

The positive slope of the yield curve leads to higher government bond yields as the maturity of the loan increases. There are two main reasons for this:

- Firstly, economic theory explains that interest rates are normally higher in the long term than in the short term, due to two simultaneous effects: the preference of debtors to borrow over the long term, and an increasingly restricted supply of credit from creditors as this term increases. Therefore, an excess of demand over the supply of credit tends to occur when the term of borrowing lengthens over time. So, there is upward pressure on the long-term interest rate relative to the short term, resulting in this differential in yields.

- Secondly, the increasing uncertainty as the term of the loan increases, which operates simultaneously with the previous one. That is, the risk that the issuer of the bond will not repay the money becomes greater as the term of the bond increases. This leads creditors to demand a higher return in the long term than in the short term, to compensate for the higher risk assumed.

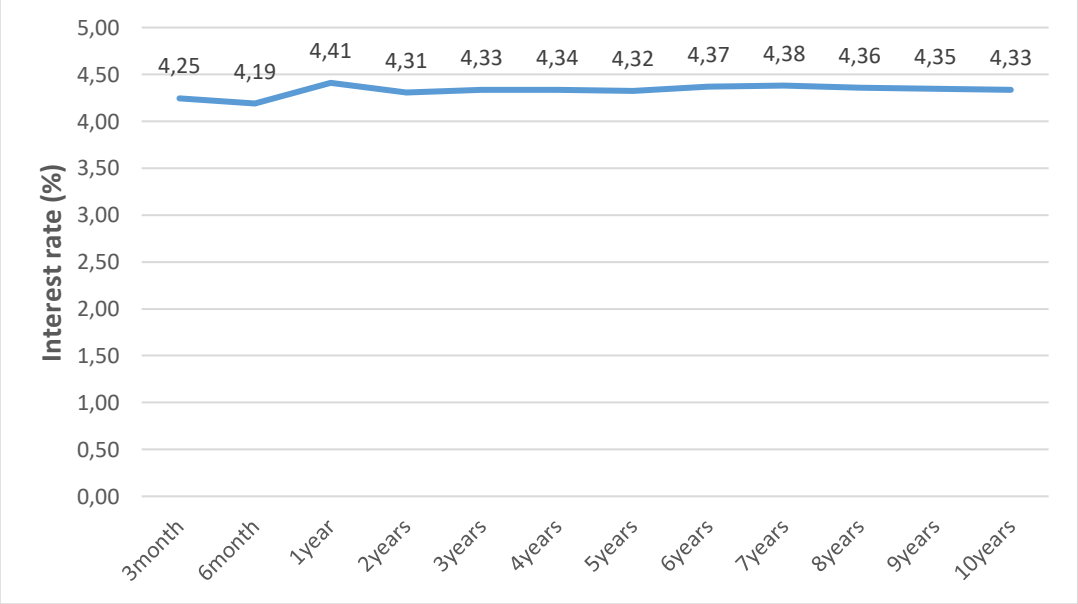
These are the main theoretical reasons for the normal behaviour of the yield curve. However, we should point out that the yield curve can take on abnormal shapes sometimes. Specifically, we say that the yield curve adopts abnormal shapes when there is a flattening or inversion of the yield curve.

Flattening or inversion of the yield curve

The flattening or inversion of the yield curve is received with some trepidation by economic agents operating in the financial market, as they believe that this could be the prelude to an economic recession. The following graph shows a flattening of the yield curve on the 8th of August 2007, when the German government gave similar yields for short-term and long-term bonds.

Figure 4.

German yield curve on 8 August 2007.

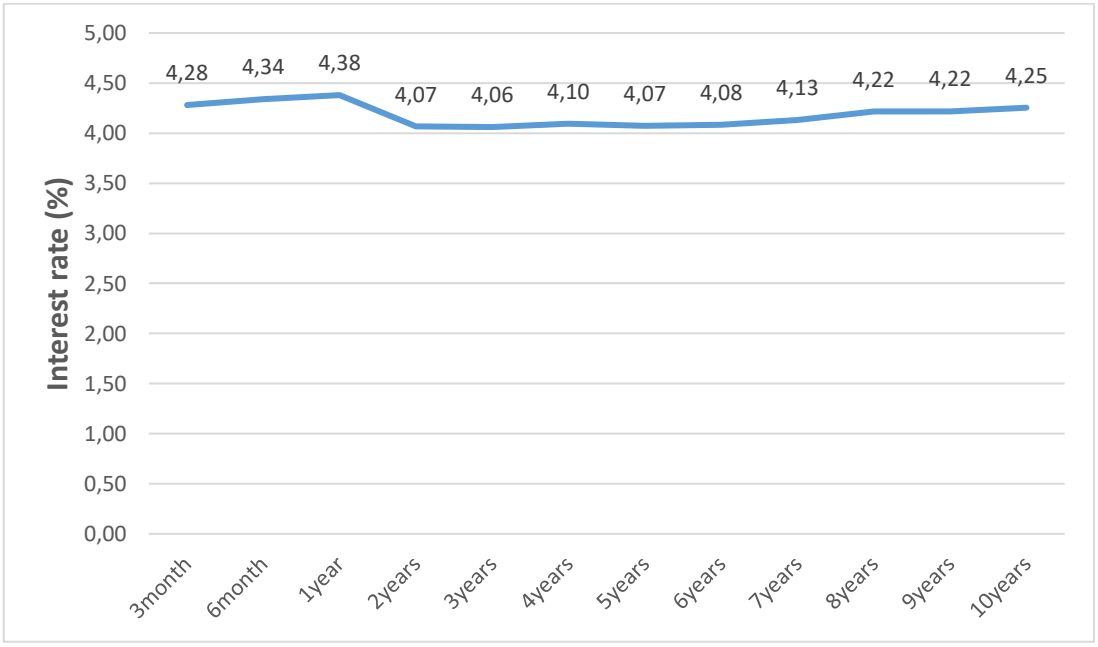


Source: own elaboration, investing.com data on 3-month to 10-year German bond yields for 8 August 2007.

On the other hand, we look at the German yield curve on the 7th of August 2008, when the German government offered better yields in the short term than in the long term, forming the inversion of the yield curve.

Figure 5.

German yield curve on 8 August 2008.



Source: own elaboration, investing.com data on 3-month to 10-year German bond yields for 8 August 2008.

As we can see in this last graph, on the 7th of August 2008, the German government was giving a higher yield on short-term bonds than on long-term bonds. Specifically, we can see the shape of the yield curve one month before the collapse of Lehman Brothers, when three-month German treasury bills offered a yield of 4.28%, while ten-year bonds offered a yield of 4.25%.

These two facts are explained by economic science for two complementary reasons, neither of which would be positive for the future growth of real economic activity.

- The first reason is to be found in the financial debt market. It focuses on the role of expectations in financial markets. If there are negative expectations about the economic future, or if a sharp economic slowdown is expected, investors will react by demanding long-term government bonds. This is because if they expect an economic downturn in the future, they will also expect future interest rates to be lower than they are today, as interest rates tend to fall in periods of recession due to the fact that, in these circumstances, there is less demand for investment than the supply of savings.

  In this way, investors will sell short-term government bonds en masse in the secondary market in order to buy long-term government bonds, which will allow them to secure higher interest rates than they expect to trade in the future. This will cause interest rates on short-term treasury bills to rise in yield, while long-

term bonds, due to high demand, will rise in price and consequently fall in yield. In conclusion, the yield curve will anticipate the recession as the repository of the superior information that would be available to market participants.

- The second reason has to do with the real side of the economy. Companies undertake productive investment projects in the medium to long term, with the precise indebtedness that, according to the calculation of their expectations, they will be able to assume in each period with the cash flows of their investment project. However, if this calculation is wrong due to an unforeseen recession, and the cash flows are not sufficient to repay the debt in each period (due to an erroneous calculation of expectations), companies will be forced to request urgent short-term financing in order to be able to meet the debt contracted that is imminently due to mature.

  Therefore, on the one hand, this will put upward pressure on short-term interest rates and, if it is a generalised crisis situation, it will put downward pressure on long-term interest rates. In this case, companies will not undertake very long-term investment projects, as their expectations in previous projects have been frustrated.

In conclusion, both reasons result from a situation of erroneous expectations due to a supervening crisis, which, through the mechanisms explained above, causes the yield curve to flatten or invert. Consequently, a flattened or inverted yield curve can be seen as a leading indicator of a forthcoming economic contraction.

Interpretation of the yield curve

The theoretical reasons we have just explained justify the different shapes that the yield curve can take. Nevertheless, we consider that it is necessary to formally demonstrate how these financial market expectations affect and influence the shape of the slope of this economic instrument. To do this, we must examine bond yields at different maturities, which will allow us to analyse and interpret what causes the slope of the yield curve to vary.

This analysis will give us insight into the expectations of the financial markets with regard to future short-term interest rates. Because we can interpret today's long-term interest rates as today's short-term interest rates plus future expectations of short-term interest rates.

To simplify this explanation, let us assume that there are only two time periods; we will call the short term as one-year bonds, and we will define the long term as two-year bonds. In this way, we can define the price of today's long-term bond ($P_{2t}€$) as referenced to the interest rate we are offered today for the long term:

Equation 3.

$$P_{2t}€ = \frac{100€}{(1 + i_{2t})^2}$$

However, we can express this same price of today's two-year bond ($P_{2t}€$) in another way. We can define it as today's one-year interest rate, plus the future expectation of the one-year interest rate in one year's time, i.e.:

Equation 4.

$$P_{2t}€ = \frac{100€}{(1 + i_{1t})(1 + i^e_{1t+1})}$$

If we equal $P_{2t}€$ from the two previous expressions, simplify and clear i_{2t} (using first order approximation, squares and products of rates are neglected) we obtain the following equation:

Equation 5.

$$i_{2t} \approx \frac{1}{2}(i_{1t} + i^e_{1t+1})$$

This equation explains that today's two-year interest rate is the average of today's one-year interest rate and the expected one-year interest rate one year from now, as we indicated at the beginning. For bonds with a longer number of years (e.g. a ten-year bond), the equation is generalised and, therefore, today's ten-year interest rate is the average of today's short-term interest rate and the short-term interest rates expected for the next nine years.

Following our analysis of the price of the two-year bond, we can also obtain the following expression:

Equation 6.

$$i^e_{1t+1} = 2i_{2t} - i_{1t}$$

Thus, by the mechanisms explained above, the expected one-year interest rate for next year is equal to twice the yield on a two-year bond minus the one-year interest rate prevailing this year.

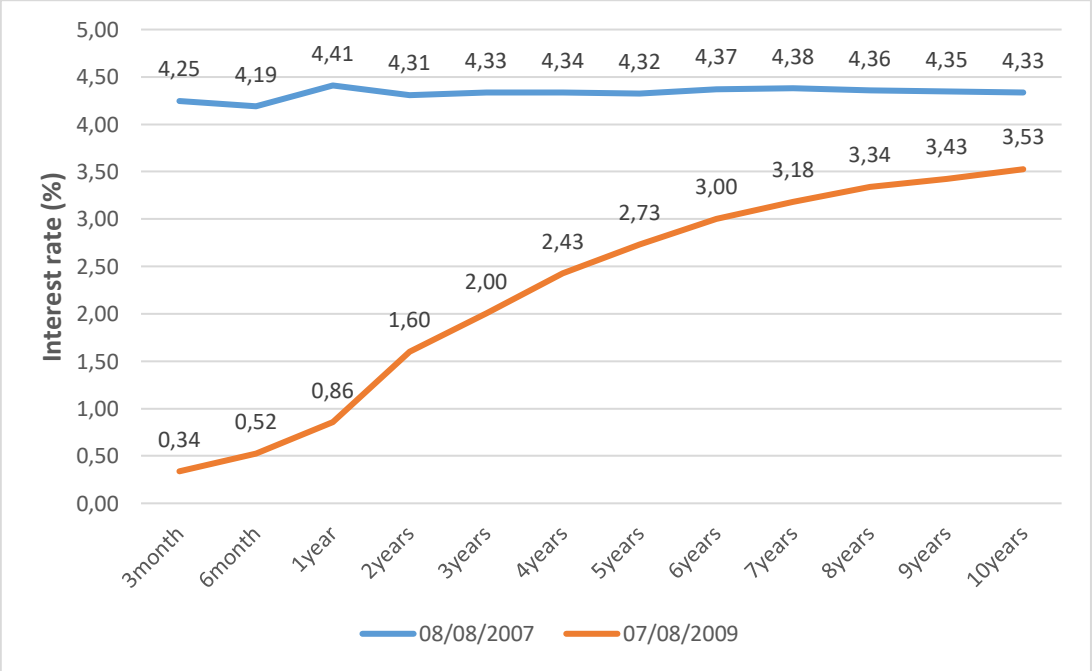
In conclusion, when the yield curve has a positive slope, it is indicating that long-term interest rates are higher than short-term interest rates, as financial markets have expectations that in the future, short-term interest rates will be higher than at present. On the other hand, when the yield curve has a negative slope, long-term interest rates are lower than short-term interest rates, and this is due to the fact that the markets' expectations are that short-term interest rates will be lower in the future than they are today.

The yield curve and real economic activity in the IS-LM model

In the previous sections, we have explained the economic theory that explains the different shapes that the yield curve can take. In particular, we have looked at the example of Germany, where we find a big difference in the way it took the yield curve in each of the periods analysed. In the following graph we can clearly observe this fact, comparing the German yield curve for 2007 and 2009.

Figure 6.

German yield curve on 7 August 2007 vs. 8 August 2009.



Source: own elaboration, data on 3-month to 10-year German bond yields from investing.com. For 8 August 2007 and 7 August 2009.

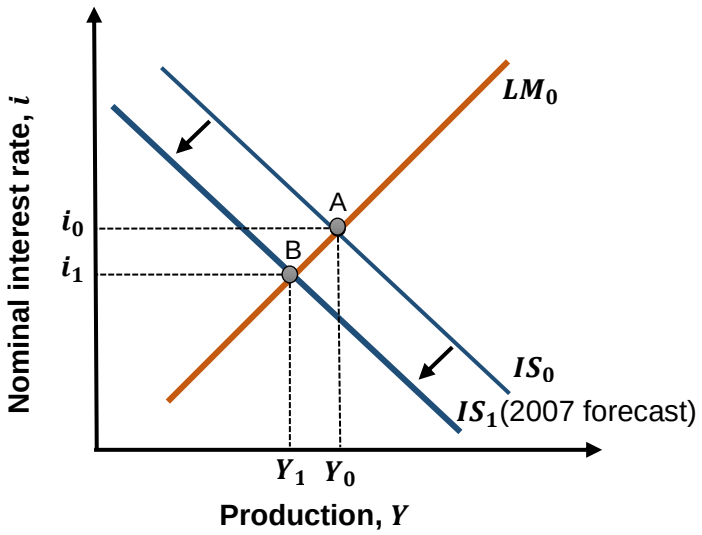
At this point, several questions arise: How can this change in the slope of the German yield curve be explained? What happened in this period in the German economy? What information would the yield curve be giving us in each of the situations?

To explain this fact in detail, we rely on the $IS - LM\ model$. For a correct analysis of this model, we will assume that we will measure on the vertical axis the short-term nominal interest rate and that this will be equal to the real interest rate, assuming zero inflation, in order to simplify our analysis and explanation.

The economic crisis of 2008 had a global impact from which an economy such as Germany (the leading European power and the third largest in the world) was not exempt. The German economy experienced negative growth of 0.4% in the second quarter of 2008 and 0.5% in the third quarter, fulfilling the technical definition of economic recession (two consecutive quarters of negative growth). However, these figures were worse than expected, according to the Dow Jones Newswire agency, which forecast a 0.1% decline in GDP in the third quarter of 2008. Moreover, according to Capital Economics, the figures indicated that "the world economy is heading towards its worst recession since the 1930s".

Figure 7.

German Economy in 2007.



This global crisis affected the German economy with a drop in the activity in its export sectors, on the other hand domestic consumption remained at low levels, and in reference to business investment, it suffered a sharp decline due to the poor business outlook.

According to a survey by the IFO institute, during October 2008, the outlook and confidence of the business world fell to its lowest level in five years. This IFO survey was

confirmed by a fall in industrial production of 3.6% and a decline in industrial orders of 8%, the biggest drop in the German economy since 1990.

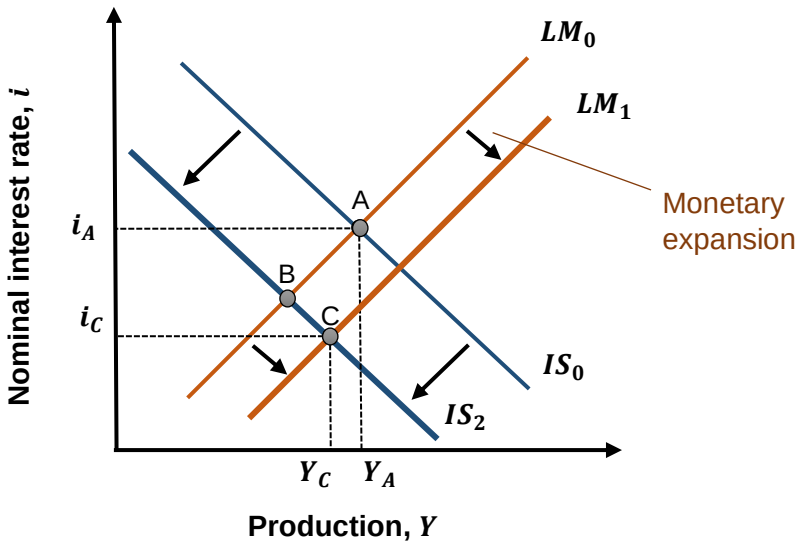
In 2007 the German economy was at a point like (A), with an interest rate i_0, and with a level of income or production Y_0. The facts explained above would lead to a predicted leftward movement of the IS curve, pushing down the interest rate i_1 and income Y_1.

This decline in expected short-term interest rates is the reason that explains the flattening of the yield curve in 2007, as financial markets had expectations that future short-term interest rates would be lower.

On 15 September 2008 we find a turning point, with the bankruptcy of Lehman Brothers. From this moment on, a period would begin where the European Central Bank would be constantly announcing extraordinary financing measures, reducing interest rates significantly in order to encourage consumption, i.e. it began to implement an expansionary monetary policy.

Figure 8.

German Economy in 2008.



As mentioned above, there was a drop in economic activity more stronger than expected, which together with the expansionary monetary policies of the European Central Bank, caused the economy to move to a point like (C).

However, in 2009 the strength of the German banking system and its industrial strength led investors to expect future growth in economic activity, due, among other reasons, to the fact that interest rates were at extremely low levels. This was reflected in the yield

curve in 2009, when the yield curve turned clearly positive, indicating that investors expected higher short-term interest rates in the future.

Figure 9.

German Economy in 2009.

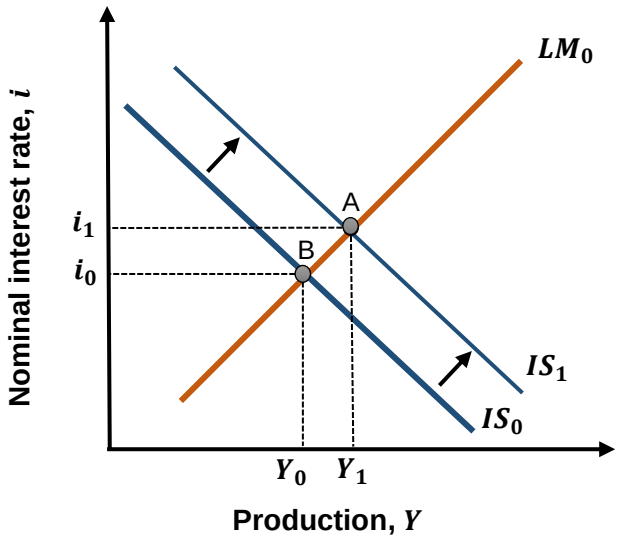


Figure 9 shows that due to the economic stimulus caused by the expansionary policies, financial markets had expectations that short-term interest rates would be higher in the future, which caused an expected shift of the IS curve to the right, shifting the IS curve from point (B) to point (A). As mentioned above, this was reflected in the positive slope of the German yield curve in 2009.

In conclusion, as we have seen in the $IS-LM\ model$, the yield curve is an instrument that reflects the expectations of the financial markets regarding future short-term interest rates.

Variables and Data description

In this study we operate with a time series database. These databases are characterised by the observation of variables over time, and are commonly used to make predictions and forecasts. A characteristic to take into account in the elaboration of these databases refers to the importance of maintaining a chronological order in time, since past events can affect future moments, but not the other way around.

As explained above, in our study we will apply two different econometric models, both with the same purpose of explaining the yield curve as a leading economic indicator of

real economic activity. However, these models will try to answer the same question, but from two different points of view:

- The first econometric model focuses on explaining the relationship between the yield curve and real economic activity.
- In the second econometric model, we will use a probability model, in which we will try to find out and explain what probability a lagged yield curve predicts in reference to an upcoming economic recession.

Given these circumstances, we have two different dependent variables in each of the models, and we will study how the term structure predicts these variables.

We will now go on to detail the data structure, as well as the definition of the economic variables we use in each of the models.

Real economic activity growth (linear regression model)

Firstly, we focus our study on explaining the yield curve and its relationship with real economic activity for the case of Germany and France. For it we will use a linear regression model.

Our dependent variable is defined as the annualised cumulative percentage change in real GDP. For its calculation, we apply the mathematical formula used by Estrella and Hardouvelis (1991).

Equation 7.

$$Y_{t,t+k} = (400/k)[\log(Y_{t+k}/Y_t)]$$

where, $Y_{t,t+k}$ is the annualised percentage increase in real GDP for the quarter $(t+k)$ with respect to quarter t. On the other hand, $(400/k)$ is the annualization factor. And finally, $[\log(Y_{t+k}/Y_t)]$ is the one-per-cent increase in real GDP in quarter $(t+k)$ with respect to quarter (t).

Regarding the search and selection of the data, we obtained them from the Federal Reserve Bank of St. Louis website. We selected a real GDP database with quarterly data, seasonally adjusted, and with a base year of 2015. For this analysis, we conducted a comparative study between two different time periods; the first study will cover a time period from the first quarter of 1970 to the last quarter of 2010, while the second period we will study will start at the same point in time and will reach the last quarter of 2020.

Given these circumstances, we will carry out a comparative study between countries and periods, specifically for the case of Germany and France. We choose these two countries as representatives of the European Union, being the two largest economic powers. In this analysis we would have liked to analyse the behaviour of our economy (Spain), but due to the restriction we face when it comes to finding historical quarterly real and seasonally adjusted GDP data, we are forced to omit it.

Finally, we want to highlight the reason for studying these two different time periods. This fact is due to the study carried out in the literature review, as we found researchers who indicate that in recent years the yield curve could have lost predictive power, so we decided to analyse this fact.

At the end of the first decade of the 2000s, we found ourselves in the most serious economic crisis since the Great Depression of 29. This crisis caused an unprecedented intervention of the European Central Bank in Europe, where expansive monetary policies were implemented that reduced interest rates to extremely low levels, therefore, the last decade (2010-2020) has been characterised by incredibly low interest rates, a fact that persists today with negative interest rates. Given this phenomenon, we consider it remarkably interesting to analyse in our research whether this fact could have made the yield curve lose its predictive capacity. By comparing the results obtained for each period, we will be able to know whether the intervention of the European Central Bank (with the implementation of expansionary monetary policies) in the last decade could have had an impact on the reduction of the predictive capacity of the yield curve for the countries studied.

Our purpose will be to find out whether we reach the same conclusions as above, since due to the current economic context we may find that the yield curve may have lost some of its predictive power, as indicated by previous research.

The probability of recession (probit model)

On the other hand, we also aim to study the predictive ability of a lagged yield curve with respect to future economic downturns.

It is important to know that probit models study dichotomous variables, i.e. variables that only take two values, one and zero, in order to explain the probability that a certain event will or will not happen. Our aim is to explain the probability of an economic recession, therefore ($RECESSIONS_t$) is our dependent or explained variable, which is a binary

variable, where in periods of economic recession the variable will take the value $(Y = 1)$ and for periods of absence the value $(Y = 0)$ is adopted.

In this model, we will study how the K quarter lagged yield curve $(SPREAD_{t-k})$ predicts future economic recessions for Germany, France, and Spain. With reference to the data for this variable, the databases for the recessionary periods for the selected countries can be found on the FRED website. These data are measured on a monthly basis, so for this analysis we will work with monthly data for the selected countries.

For the case of Germany we will study a time horizon from 1970:01 to 2020:M12. In the case of France, we will study a time horizon from 1971:M01 to 2020:M12. Finally, in the case of Spain, we will have to adapt to the data available to us, so we will study a time horizon from 1981:M01 to 2020:M12.

The study of this dependent variable $(RECESSIONS_t)$ in the probit model has been widely used by many researchers in the past, yielding very positive conclusions on the predictive power that a lagged yield curve in K quarters $(SPREAD_{t-k})$ would give us. Therefore, we will try to find out, in view of the results we obtain in our research, whether we reach these same conclusions.

Table 2.

Periods of economic recession.

Recessions Indicators Series		
GERMANY (1970:01-2020:12)	*FRANCE (1971:01-2020:12)*	*SPAIN (1981:01-2020:12)*
1970:09 - 1972:02	1971:11 - 1972:08	1980:06 - 1981:11
1973:05 - 1975:06	1974:03 - 1975:07	1983:06 - 1986:10
1979:12 - 1982:09	1980:01 - 1981:02	1991:11 - 1993:06
1985:10 - 1987:04	1982:06 - 1987:03	1995:07 - 1996:12
1991:04 - 1993:09	1990:03 - 1993:10	2000:12 - 2004:04
1995:01 - 1996:02	1995:04 - 1997:02	2008:03 - 2009:07
1998:02 - 1998:12	2000:12 - 2003:06	2011:04 - 2013:08
2001:05 - 2005:02	2008:02 - 2009:06	2017:10 - 2020:05
2008:03 - 2009:06	2011:10 - 2013:02	
2011:08 - 2013:03	2013:12 - 2016:08	
2014:04 - 2015:05	2019:04 - 2020:05	
2017:12 - 2020:05		

Source: Federal Reserve Bank of St. Louis

SPREAD

As we have been reiterating since the beginning of this paper, our object of study is to answer the following question: Is the yield curve a good predictive instrument for changes in the business cycle? Consequently, our aim is to explain the predictive ability of the yield curve ($SPREAD_t$), whether it can be a good leading economic indicator and, consequently, whether it can explain the growth of real economic activity and recessions.

We define our independent or explanatory variable for both econometric models as the spread of long-term versus short-term bond yields. However, we can qualify that in our linear regression model we use the spread of yields at the current point in time ($SPREAD_t$), while in the probit model we use the spread of yields lagged by K quarters ($SPREAD_{t-k}$), to explain the probability of an economic recession ($RECESSIONS_t$).

In reference to the definition of this variable, this can be defined as the difference between the interest rates on long-term bonds versus the interest rates on short-term treasury bills, as we can see in the following equation:

Equation 8.

$$SPREAD_t \equiv R_t^L - R_t^S$$

where, R_t^L refers to long-term bond yields, and R_t^S refers to short-term bond yields.

In reference to the search and selection of the data, we found the information on the interest rates of short and long-term bonds on the OECD[4] website, which informs us that the data provided are referenced to:

- Short-term interest rates: “Short-term interest rates are the rates at which short-term borrowings are effected between financial institutions or the rate at which short-term government paper is issued or traded in the market. Short-term interest rates are generally averages of daily rates, measured as a percentage. Short-term interest rates are based on three-month money market rates where available” (OECD).

- Long-term interest rates: “Long-term interest rates refer to government bonds maturing in ten years. Rates are mainly determined by the price charged by the lender, the risk from the borrower and the fall in the capital value. Long-term interest rates are generally averages of daily rates, measured as a percentage. These interest rates are implied by the prices at which the government bonds are

[4] OECD: Organisation for Economic Co-operation and Development

traded on financial markets, not the interest rates at which the loans were issued. In all cases, they refer to bonds whose capital repayment is guaranteed by governments" (OECD).

Finally, the periodicity of the data we have selected is monthly, since the data of the dependent variable are measured monthly, given this fact we selected this temporal measure for this econometric model.

Econometric Models

Linear regression model

This first econometric model allows us to study the relationship between the yield curve $(SPREAD_t)$ and real economic activity $(Y_{t,t+k})$..

Our model relating these two variables is (Equation 1) referred to above:

$$Y_{t,t+k} = \alpha_0 + \alpha_1 SPREAD_t$$

The constants α_0 and α_1 are the parameters of the econometric model and describe direction and strength between real economic activity and the yield curve. Our analysis aims to explain how changes in the yield curve $(SPREAD_t)$ affect real economic activity $(Y_{t,t+k})$.

This model relates the spread of today's bond yields $(SPREAD_t)$ to the growth rate of the economy within K quarters. Therefore, the parameter estimated under our hypothesis will have to be negative and significant. Quantitatively, it is the change in the dependent variable with respect to one unit change in the independent variable.

One problem encountered in the estimation of this model is autocorrelation. Estrella and Hardouvelis (1991) already referred to this problem, and to solve it these authors indicate the following: "In order to make correct inferences, the OLS standard errors must be adjusted. We use the adjustment method of Newey and West (1987)". So in our research we follow this method to overcome the autocorrelation problem.

Probit model

In our analysis, the term structure ($SPREAD_t$) could be a better predictor for a binary variable, that is to say, a probability model explaining the presence or absence of an economic recession.

In order to analyse this issue, we will rely on econometric probability models. However, when estimating and using the linear probability model, a very important drawback is found. This refers to the fact that the adjusted probabilities can give us results that are outside the range (0, 1), that is, we can find results with probabilities greater than one and less than zero.

This problem found in the linear probability model can be overcome with the application of more complex binary response models: we refer to the Logit and probit model. In these, the adjustments of the dependent variable will be between one and zero, therefore, it allows us to interpret the probability of a certain event happening or not, given the values of the independent variables and once the parameters have been estimated.

To explore this question we use a probit model, which relates the probability of an economic crisis in the current quarter ($RECESSIONS_t$), to the slope of the delayed yield curve in K quarters. To apply this analysis we use (Equation 2) explained above:

$$\Pr(\mathrm{X} = 1|SPREAD_{t-k}) = \mathrm{F}(\beta_0 + \beta_1 SPREAD_{t-k})$$

where, $\Pr$ denotes probability, F is the cumulative normal distribution and X is equal to unity, during quarters considered as recessions.

ANALYSIS OF THE RESULTS

In order to carry out a structured analysis of the results, we will divide this section into two sections. Firstly, we will try to explain the results obtained in the linear regression model, which will indicate the relationship between the yield curve and real economic activity, and we will also check the results obtained by graphically representing this relationship. Secondly, we will analyse the results of the probit model, where we will make a graphical representation of the probabilities of an economic recession with the information provided by a delayed yield curve in K quarters.

Table 3.

Results of the linear regression model, for Germany (1970:Q1 – 1995:Q4), (1970:Q1 – 2010:Q4) and (1970:Q1 – 2020:Q4).

	Period (1970:Q1 -1995:Q4)			Period (1970:Q1-2010:Q4)			Period (1970:Q1-2020:Q4)		
Forecasting Horizon; K Quarters Ahead	*const*	$SPREAD_t$	$\bar{R}^2$	*const*	$SPREAD_t$	$\bar{R}^2$	*const*	$SPREAD_t$	$\bar{R}^2$
1	2.15*** (0.47)	0.44** (0.20)	0.03	1.55*** (0.51)	0.51** (0.23)	0.03	1.32*** (0.49)	0.56** (0.24)	0.02
2	2.06*** (0.39)	0.50*** (0.16)	0.10	1.46*** (0.46)	0.56*** (0.20)	0.08	1.24*** (0.44)	0.60*** (0.21)	0.06
3	2.02*** (0.35)	0.53*** (0.13)	0.17	1.42*** (0.42)	0.56*** (0.18)	0.12	1.13*** (0.42)	0.64*** (0.19)	0.11
4	2.00*** (0.32)	0.55*** (0.11)	0.26	1.40*** (0.39)	0.57*** (0.15)	0.16	1.16*** (0.38)	0.63*** (0.16)	0.15
5	2.02*** (0.31)	0.55*** (0.10)	0.28	1.42*** (0.37)	0.54*** (0.14)	0.17	1.22*** (0.35)	0.59*** (0.14)	0.15
6	2.03*** (0.29)	0.54*** (0.10)	0.32	1.44*** (0.34)	0.52*** (0.12)	0.18	1.27*** (0.31)	0.55*** (0.12)	0.16
7	2.05*** (0.27)	0.51*** (0.09)	0.33	1.46*** (0.32)	0.48*** (0.11)	0.18	1.32*** (0.29)	0.51*** (0.11)	0.16
8	2.08*** (0.26)	0.46*** (0.08)	0.31	1.50*** (0.30)	0.44*** (0.10)	0.17	1.38*** (0.27)	0.45*** (0.10)	0.15
12	2.16*** (0.23)	0.30*** (0.09)	0.20	1.68*** (0.23)	0.27*** (0.10)	0.11	1.55*** (0.21)	0.29*** (0.10)	0.11
16	2.20*** (0.17)	0.22*** (0.08)	0.17	1.75*** (0.16)	0.20** (0.08)	0.10	1.60*** (0.16)	0.23*** (0.09)	0.12
20	2.29*** (0.14)	0.14** (0.05)	0.11	1.83*** (0.13)	0.13** (0.06)	0.05	1.67*** (0.14)	0.16** (0.07)	0.08

*Note: own elaboration, we use the econometric software Gretl. ***Significant at the 1% level, **significant at 5%, and *significant at 10%, in a two-tailed test.*

Table 4.

Results of the linear regression model, for France (1970:Q1 – 1995:Q4), (1970:Q1 – 2010:Q4) and (1970:Q1 – 2020:Q4).

	Period (1970:Q1 -1995:Q4)			Period (1970:Q1-2010:Q4)			Period (1970:Q1-2020:Q4)		
Forecasting Horizon; K Quarters Ahead	*const*	$SPREAD_t$	$\bar{R}^2$	*const*	$SPREAD_t$	$\bar{R}^2$	*const*	$SPREAD_t$	$\bar{R}^2$
1	2.19*** (0.35)	0.45*** (0.17)	0.09	1.80*** (0.35)	0.48*** (0.16)	0.08	1.44*** (0.51)	0.48** (0.20)	0.00
2	2.14*** (0.31)	0.50*** (0.15)	0.16	1.74*** (0.34)	0.53*** (0.15)	0.14	1.40*** (0.45)	0.52*** (0.18)	0.02
3	2.13*** (0.29)	0.51*** (0.14)	0.21	1.71*** (0.32)	0.55*** (0.15)	0.18	1.22*** (0.45)	0.59*** (0.18)	0.06
4	2.12*** (0.27)	0.51*** (0.13)	0.24	1.71*** (0.30)	0.55*** (0.14)	0.20	1.28*** (0.38)	0.54*** (0.15)	0.08
5	2.17*** (0.26)	0.46*** (0.12)	0.23	1.75*** (0.29)	0.51*** (0.13)	0.20	1.41*** (0.33)	0.46*** (0.14)	0.07
6	2.20*** (0.24)	0.41*** (0.12)	0.20	1.79*** (0.28)	0.46*** (0.13)	0.18	1.51*** (0.29)	0.38*** (0.13)	0.06
7	2.23*** (0.23)	0.36*** (0.11)	0.18	1.83*** (0.26)	0.43*** (0.12)	0.17	1.57*** (0.27)	0.33*** (0.12)	0.06
8	2.25*** (0.22)	0.32*** (0.10)	0.16	1.86*** (0.25)	0.39*** (0.12)	0.15	1.63*** (0.25)	0.29** (0.12)	0.05
12	2.27*** (0.24)	0.21*** (0.10)	0.08	2.01*** (0.21)	0.24*** (0.09)	0.09	1.78*** (0.21)	0.17* (0.09)	0.03
16	2.29*** (0.23)	0.15*** (0.11)	0.05	2.07*** (0.16)	0.18** (0.08)	0.07	1.79*** (0.19)	0.15* (0.09)	0.03
20	2.33*** (0.18)	0.10** (0.08)	0.03	2.14*** (0.13)	0.11 (0.07)	0.04	1.84*** (0.17)	0.09 (0.08)	0.01

*Note: own elaboration, we use the econometric software Gretl. ***Significant at the 1% level, **significant at 5%, and *significant at 10%, in a two-tailed test.*

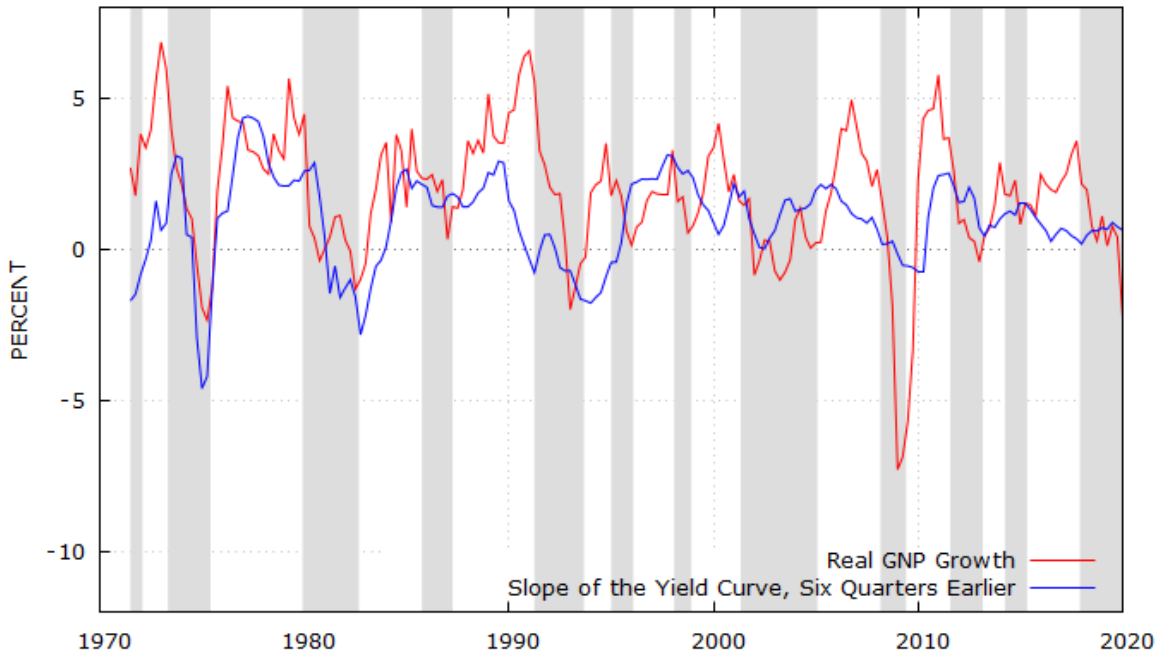
Results of the linear regression model

First of all, we focus our analysis on the German economy, which is the leading European economic power, so we believe that we could obtain results similar to those obtained by Estrella and Hardouvelis (1991). Once the parameters have been estimated, we obtain the results shown in table 3.

In table 3, we can observe a very important fact, and this is related to the loss of the predictive ability of the yield curve in recent years. These results are already explained previously by other researchers, who refer to the loss of predictive ability of the yield curve in recent years.

Figure 10.

Forecasted probability of recession for current quarter based on the slope of the yield curve 6 quarters earlier for Germany (1970:Q1-2020:Q4).



Note: own elaboration, we use the econometric software Gretl.

As we can see, in the first time period studied we obtain the best relationship between the yield curve and the growth of real economic activity at a time horizon of six and seven quarters, with an $\bar{R}^2$ reaching 32% and 31% respectively. These results are similar to those obtained by Estrella and Hardouvelis (1991) for the United States. However, adding the data up to 2010:M12, we can already observe how this relationship loses an important predictive capacity, obtaining an $\bar{R}^2$ of 18% for the same time horizon. Finally, when we add the last decade to the analysis, this relationship decreases even more, obtaining an $\bar{R}^2$ of 16%.

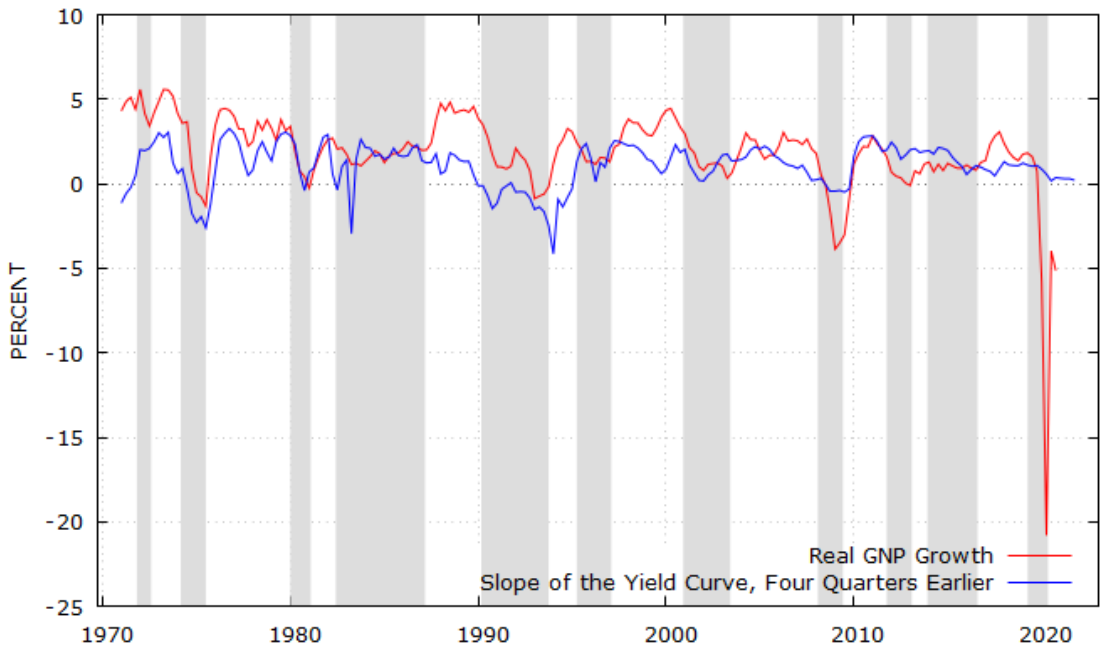
To check these results, we can graphically represent this relationship by comparing the growth of real economic activity with the information that would be provided by a six-quarter lagged yield curve.

In view of figure 10, we can confirm the results obtained in our linear regression model. The first half of the period the yield curve would be better related to the growth of real economic activity, so we can corroborate the results obtained, where we explain that this economic indicator would have lost some predictive capacity in recent years for the German economy. However, we would like to point out that the yield curve would still provide us with relevant information regarding the growth of real economic activity in the case of Germany.

On the other hand, with reference to the case of France, we carried out the same analysis that we have just done for the German economy, in order to compare the results obtained for these countries. Once this econometric model has been estimated, we obtain the results shown in table 4.

Figure 11.

Forecasted probability of recession for current quarter based on the slope of the yield curve 4 quarters earlier for France (1970:Q1-2020:Q4).



Note: own elaboration, we use the econometric software Gretl.

As we can see in the two periods analysed, if we compare the $\bar{R}^2$ in the same time horizon we obtain very different results. This would indicate that in the last decade (2010-

2020) the French yield curve would have lost some of its predictive capacity to explain future growth rates of real economic activity. As we can see, in the period 1970:M1-2010:M12 the yield curve would explain real economic activity, with a time horizon of four and five quarters, with an $\bar{R}^2$ of 20%. However, if we add the last ten years, this model would only explain 8% of the growth in real economic activity over the best time horizon.

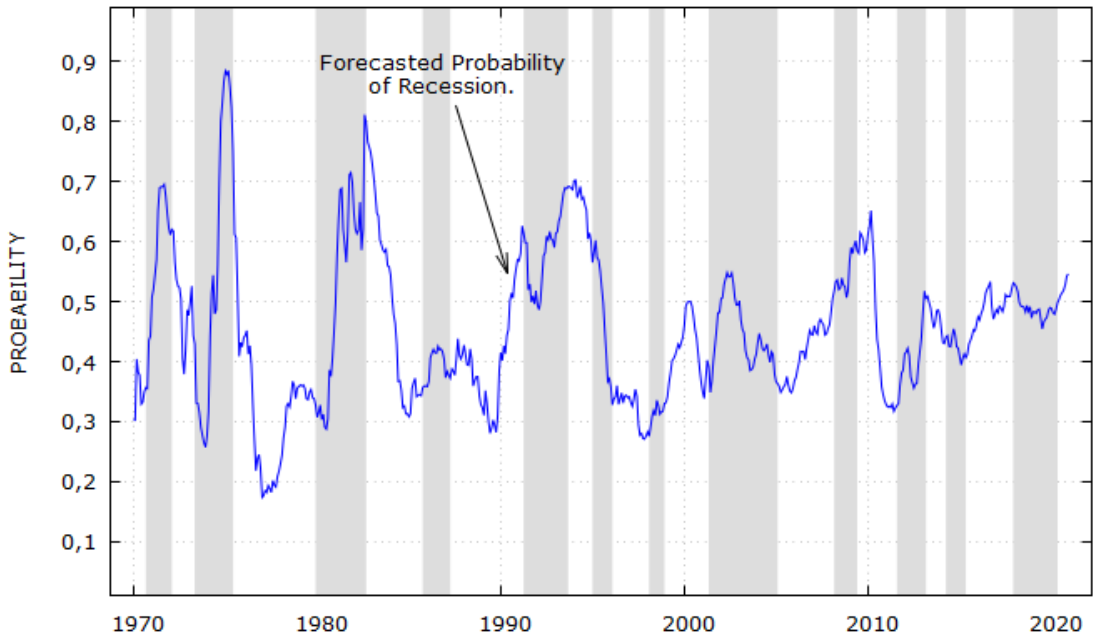
Results of the probit model

Our investigation continues with the application of the probit model, which provides us with the probability of a forthcoming economic recession with the information of a lagged yield curve in K quarters. For a better understanding of the results, we will proceed to represent these results graphically. On the other hand, the case of the Spanish economy will be included in this analysis.

Firstly, as in the first econometric model, we start by analysing the results for Germany. After estimating the model we obtain the following results:

Figure 12.

Expected probability of recession for the current quarter based on the slope of the yield curve 6 quarters earlier for Germany (1970:M1 – 2020:M12).



Note: own elaboration, we use the econometric software Gretl.

We find very encouraging results, as we observe that this model provides us with similar results to the US case, and as we can see it presents very favourable results, as the

yield curve would have provided us with relevant information regarding the next economic recessions one year in advance.

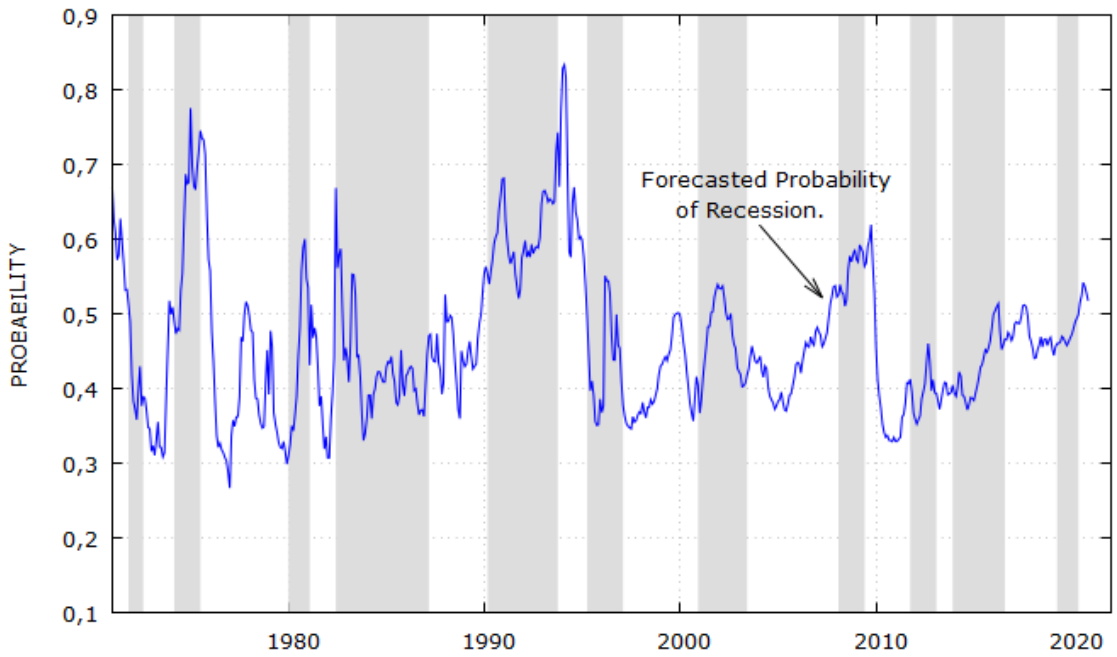
However, we find that the yield curve would not be as explanatory as it was at the end of the last century. As we have already observed in the results provided by the linear regression model, this fact is also confirmed in this econometric model.

As we can see in figure 11, the probit model would give us good results, although in the last decade we can observe how this relationship would have reduced. As we have explained above, this last decade has been marked by the monetary policies of the European Central Bank, a fact that would have absorbed an important predictive capacity of the yield curve.

On the other hand, we have the case of France, where in view of the results obtained in the first econometric model, we would have to confirm in this model the significant loss of the predictive capacity of the French yield curve.

Figure 13.

Expected probability of recession for the current quarter based on the slope of the yield curve 4 quarters earlier for France (1971:M1 – 2020:M12).



Note: own elaboration, we use the econometric software Gretl.

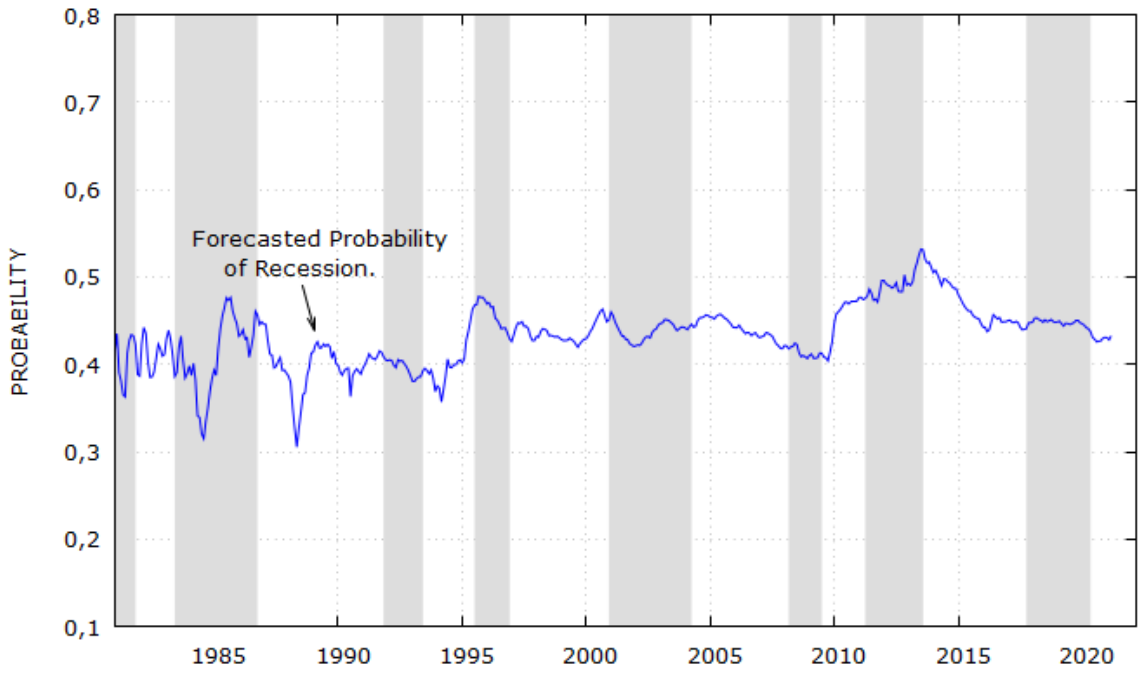
As we can see in figure 12, until 1995 the French yield curve would have explained the growth of real economic activity very well, predicting all economic recessions to date.

However, since the beginning of the 21st century, the yield curve would have lost an important predictive power.

Finally, we have the case of the Spanish economy. In the first econometric model we have been forced to omit this economy from our study, due to the data restriction found. Due to the economic size, we thought that the Spanish economy would be closer to the French economy than the German one, so we decided to study a four-quarter lagged yield curve (same case as France) as a predictor of economic recessions.

Figure 14.

Expected probability of recession for the current quarter based on the slope of the yield curve 4 quarters earlier for Spain (1981:M1-2020:M12).



Note: own elaboration, we use the econometric software Gretl.

Therefore, in view of the econometric models studied, we believe that the yield curve is a leading economic indicator that would work well in the case of the German economy, however, currently the yield curve does not provide us with sufficient and relevant information to explain and predict future economic recessions and the growth of real economic activity in France and Spain.

CONCLUSIONS

Given the results achieved in this research, we can reach different conclusions. We consider it important to assess and analyse each one of them in detail, since we observe a specific behaviour of the yield curve for each of the economies analysed. However, from our point of view, given the simple application and interpretation of this economic instrument, the information it would provide us in relation to future growth rates of real economic activity would be important in our study. On the other hand, we find differences in the predictive capacity for future economic recessions, depending on the country chosen. Next, we will proceed to make a detailed explanation of all these facts and conclusions.

First of all, we want to refer to the conclusions obtained in the application of our linear regression model. In this case, we observe a similar behaviour for both Germany and France in the period studied until the end of 2010. However, we can verify a loss in the predictive ability of the yield curve when we extend the time period up to 2020, in which we highlight a significant loss in the relationship between the yield curve and real economic activity for the case of France.

This significant reduction observed in the case of France, we believe that it could be due to the consequences and economic measures brought by the financial crisis of 2008, where the European Central Bank from 2009 began to apply unprecedentedly expansive monetary policies, reducing interest rates to extremely low levels. This fact persists in time until today, with negative interest rates.

On the other hand, this loss in the predictive capacity of the yield curve is minimal in the case of the German economy, in which the model only suffers a loss of between 1% and 2%. This fact could be due to its economic situation, where the expansionary monetary policies carried out by the European Central Bank would not have significantly affected this indicator in the last decade. Moreover, we have already verified this fact previously, when we explained the $IS - LM\ model$, where we see the rapid recovery that occurred in Germany from the 2008 economic crisis. Therefore, we understand that this model would significantly explain future growth rates of real economic activity for Germany.

Referring to the results obtained by Estrella and Hardouvelis (1991) for the United States, the relationship between the yield curve and real economic activity in Germany would be smaller than in the US case. Although we understand that we cannot draw important conclusions from this fact, since the referred study of the United States covers a time period very different from ours, and there is also a difference in the economic size of

these countries, so that we cannot directly compare these results. To solve this problem, it would be interesting to analyse how the German yield curve would have behaved in the same period as the one studied by Estrella and Hardouvelis (1991), however we believe it is more relevant to focus our study on knowing the behaviour of the yield curve currently.

In short, with the application of this first econometric model, we conclude that there is a significant relationship between the yield curve and real economic activity in the case of Germany, although we observe that this relationship would have lost strength in the last decade. We believe that by applying this economic technique we should take into account the specific characteristics of the country under study, since in our work we obtain specific results for each country, so we cannot conclude that the yield curve works in a similar way in all countries.

Second, in relation to the probabilities of a forthcoming economic recession, we again observe different behaviour across the countries studied. The application of the lagged yield curve in the probit model provides us with good results for the case of Germany, this result being similar to that obtained by Estrella and Hardouvelis (1991) for the United States. With reference to the case of France, the yield curve would have lost much predictive power, and finally in the case of Spain we would not obtain good results in any period.

We think that given Germany's preeminent position in the economic context of the European Union, if we wish to obtain relevant information regarding the growth of real economic activity in the countries of the European economic environment, we should pay special attention to the German yield curve. This fact it is due to a specific characteristic of the EU member countries, where all of them share monetary policy, which leads, among other reasons, to the fact that they are economies with a strong interdependence.

In relation to these ideas, we want to cite the example of the risk premium, which is an economic indicator that compares the solvency of public debt between countries. In the European case, the zero risk bonds are those issued by the German government, so all bonds issued by other European countries are referenced to German bonds in terms of solvency. Consequently, we think that this criterion would also apply to the yield curve, i.e. to have the German yield spread as a benchmark.

Finally, we consider that economic agents interested in predicting the European economic future should pay special attention to the German yield curve. However, this fact does not mean that we cannot also analyse the French and Spanish yield curves,

although we consider that the results we obtain will probably not be as relevant as in the case of the German economy. Our contribution is referenced to this difference that we have observed in our research for the European countries studied, taking into account the economic, demographic and social characteristics of each country.

We understand that the application of this economic technique could be a perfect complement for the more complex models used to predict changes in the economy. However, given its simple application, it would be an important tool for households and firms, which do not have other more complex mechanisms to address this issue. Consequently, we consider the yield curve to be an easy leading economic indicator to analyse and interpret, since by observing the slope of this instrument or by comparing long-term and short-term bond interest rates, we could get an idea of the possible changes that may occur in real economic activity.

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APENDIX

Probit model

Probability models allow us to explain the probability of a given event occurring or not, given the behaviour and effect of the independent variables.

The probit model, like the linear probability model, uses a dichotomous dependent variable, which, as mentioned above, assumes only two values, zero and one. However, the probit model is a non-linear regression model, which overcomes the problem found in the linear probability model. The following equation shows the general equation of the probit model.

Equation 9.

$$\Pr(\mathrm{Y}=1|\mathrm{X}) = \mathrm{F}(\beta_0 + \beta_1 x_1 + \cdots + \beta_k X_k)$$

Where, Pr is a function that assumes values between zero and one: $(0 < F(z) < 1)$ for all real numbers (z). This ensures that the estimated response probabilities are strictly between zero and one. On the other hand, F is the standard normal distribution function, which represents the cumulative probability from $(-\infty, z)$, according to the following equation:

Equation 10.

$$F(z) = \int_{-\infty}^{z} \emptyset(v)dv,$$

where, $\emptyset\ (v)$ is the standardised normal density function:

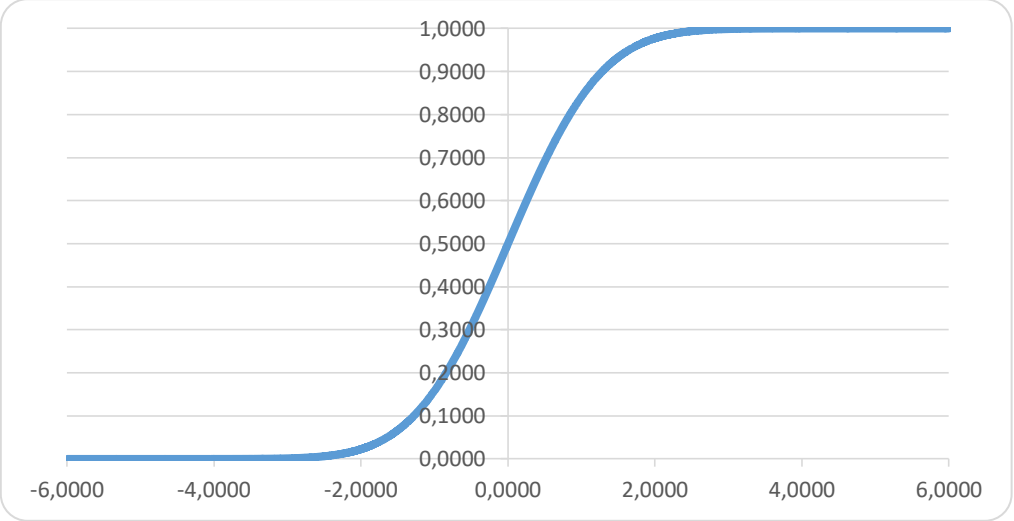
Equation 11.

$$\emptyset(v) = (2\pi)^{-1/2}\exp(\frac{-v^2}{2})$$

We can see graphically how this distribution function is represented, and we can see why it will give us probabilities that are between (0, 1).

Figure 15.

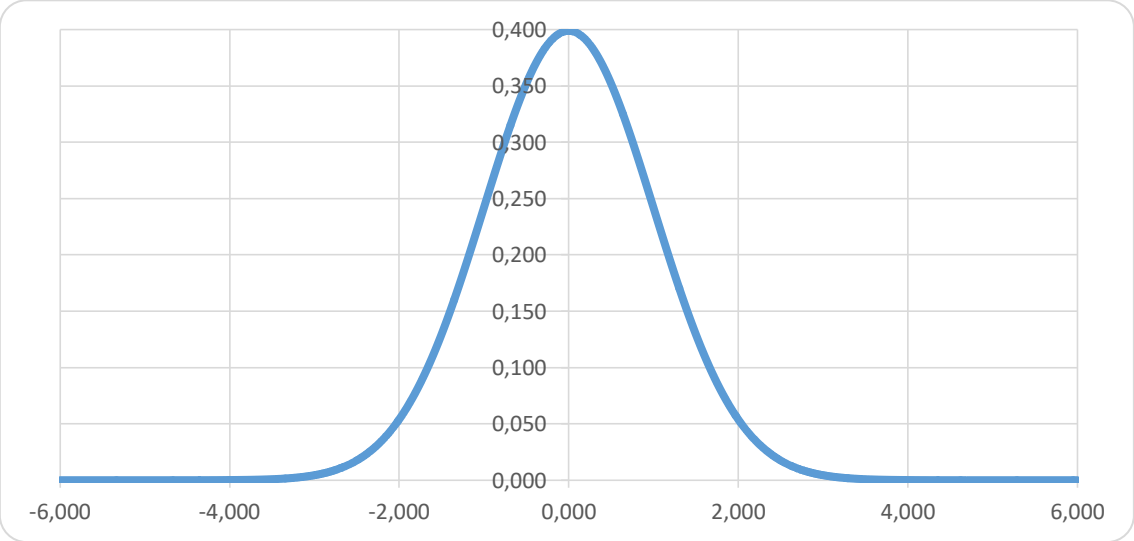
Graphical representation of the distribution function.



Source: own elaboration.

Figure 16.

Graphical representation of the standard normal distribution N (0, 1).



Source: own elaboration.